A SUPPLEMENT

TO

URE'S DICTIONARY

OF

ARTS, MANUFACTURES, AND MINES,

CONTAINING

A CLEAR EXPOSITION OF THEIR PRINCIPLES AND PRACTICE.

FROM THE LAST EDITION,

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ASSISTED BY NUMEROUS CONTRIBUTORS EMINENT IN SCIENCE AND FAMILIAR WITH MANUFACTURES.

ILLUSTRATED WITH SEVEN HUNDRED ENGRAVINGS ON WOOD.

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1868.
This Volume of Ure's Dictionary of Arts, Manufactures, and Mines, contains the additional knowledge which has accumulated within the past ten years. Not a year has passed but that some important improvements in the Arts and Sciences have taken place, all of which form an important increase to knowledge, which cannot well be dispensed with by those who are engaged in the various pursuits in which they are employed.

The following are a few, among the many, who are specially interested, viz.:

PREFACE.

Ure’s Dictionary of Arts, Manufactures, and Mines has long had the reputation of a standard authority upon the subjects of which it treats. But such is the inventive activity of the age, and the rapid improvement in art processes, that a work of this kind can only maintain its character by frequent and extensive additions. While the distinguished author was in the vigor of his intellect, the revisions of the work kept pace with the progress of improvement, but at his demise it was found necessary to organize a plan for bringing up the Dictionary to the present state of knowledge. Accordingly, Mr. Robert Hunt, a gentleman whose high scientific position gave warrant that the work would be well performed, assumed the editorship, and a corps of the ablest practical and scientific men in England was secured to prepare articles in their several departments. The following remarks, condensed from the preface to the English edition, will explain the purpose and plan of the editor.

"The objects which have been steadily kept in view are the following: To furnish a work of reference on all points connected with the subjects included in its design, which should be of the most reliable character. To give to the scientific student and the public the most exact details of those manufactures which involve the application of the discoveries of either physics or chemistry. To include so much of science as may render the philosophy of manufactures at once intelligible, and enable the technical man to appreciate the value of abstruse research."

"I commenced the new edition of Ure’s Dictionary with an earnest determination to render the work as complete and as correct as it was possible for me to make it. In my necessities I have asked the aid of the manufacturer, and the advice of the man of science, and never having been refused the aid solicited, I am led to hope that those who may possess these volumes will find in them more practical knowledge than exists in any work of a similar character."

This volume of Ure’s Dictionary contains the chief additions made to the late English edition. Those portions of the work which concerned mainly the English, their commercial and manufacturing resources and statistics, the least important historic notices, and some definitions in pure science, which seemed hardly embraced within the defined scope of the work, have been omitted. By this means the original and valuable contributions to the work have been brought within the limits of a single
volume, which has lost nothing of its real value. This supplementary volume is rich with the latest results of inquiry, containing all the new and important matter and illustrations of the three English volumes, costing $28, while the complete American edition of the work, in three volumes, comprising 3212 pages, with 2300 engravings, forms the completest repertory of arts, manufactures, and mines, which has been yet published.

Subjoined is a list of the contributors, whose initials will be found appended to their respective articles.

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SUPPLEMENT

to

DICTIONARY OF ARTS, MANUFACTURES, AND MINES.

ABA. A woollen stuff manufactured in Turkey.

ABACA. A species of fibre obtained in the Philippine Islands in abundance. Some authorities refer these fibres to the palm-tree known as the Abaca, or Anisa textilis. There seem, indeed, several well-known varieties of fibre under this name, some so fine that they are used in the most delicate and costly textures, mixed with fibres of the pine-apple, forming Pina muslins and textures equal to the best muslins of Bengal. Of the coarser fibres, mats, cordage, and sail-cloth are made. M. Duchesne states, that the well-known fibrous manufactures of Manilla have led to the manufacture of the fibres themselves, at Paris, into many articles of furniture and dress. Their brilliancy and strength give remarkable fitness for bonnets, tapestry, carpets, network, hammocks, &c. The only manufactured articles exported from the Philippine Islands, enumerated by Thomas de Comyn, Madrid, 1820 (transl. by Walton), besides a few tanned buffalo hides and skins, are 8,000 to 12,000 pieces of light sail-cloth, and 200,000 lbs. of assorted abaca cordage.

ABIES (in Botany), the fir, a genus of trees which belong to the coniferous tribe. These trees are well known from their ornamental character, and for the valuable timber which they produce. They yield several resins or gum resins, which are useful in the arts.

ABIES BALSAMEA (the Balm of Gilead fir) produces the Canadian balsam. This tree grows most abundantly in the colder regions of North America.

ABIES CANADENSIS (the hemlock spruce fir). A considerable quantity of the essence of spruce is extracted from the shoots of this tree; it is, however, also obtained from other varieties of the spruce fir.

ABIES PICEA of Linnæus (Abies pectinata of De Candolle). The Silver fir, producing the Burgundy pitch and the Strasbourg turpentine.

ABLÉTÉ, or ABLE, is a name given to several species of fish, but particularly to the Bleak, the scales of which are employed for making the pearl essence which is used in the manufacture of artificial pearls. See PEARLS, ARTIFICIAL.

ABRASION. The Figuration of materials by wearing down the surface. See File, vol. i.

ACACIA. (L. acacia, a thorn; Gr. ἄκακος, a point.) The acacia is a very extensive genus of trees or shrubby plants, inhabiting the tropical regions generally, but extending in some few instances into the temperate zone; being found, for example, in Australia, and the neighboring islands. Botanists are acquainted with nearly 300 species of the acacia; some of these yield the gum arabic and the gum catechu of commerce; while the bark of others yields a large quantity of tannin, especially a variety which grows in Van Diemen's Land, or Tasmania. See Arabic Gum; Catechu.

ACACIA ARABICA. An inhabitant of Arabia, the East Indies, and Abyssinia. One of the plants yielding the gum arabic, which is procured by wounding the bark of the tree, after which the sap flows out and hardens in transparent lumps.

ACACIA CATECHU. The catechu acacia (Mimoso catechu of Linnæus) is a tree with a moderately high and stout stem, growing in mountainous places in Bengal and Coromandel, and in other parts of Asia. Its unripe pods and wood, by decoction, yield the catechu or terra Japonica of the shops.

ACÉSCENT. Substances which have a tendency to pass into an acid state; as an infusion of mait, &c.
ACETAL. (C₄ H₄ O₄) One of the products of the oxidation of alcohol under the influence of the oxygen condensed in platinum black. It is a colorless, mobile, ethereal liquid boiling at 221° F. Its density in the fluid state is 0.821 at 72°. The specific gravity of its vapor 4.138 slps. (mean of three experiments); calculation gives 4.083 for four volumes of vapor.—For the description of the modes of determining vapor volume, consult some standard chemical work.—The recent researches of Wurtz render it evident that the constitution of acetal is quite different to what has generally been supposed, and that it is in fact glycéridéthyle; that is to say, glycole in which two equivalents of hydrogen are replaced by two equivalents of ethyl. —C. G. W.

ACETATE. (Acetate, Fr.; Essignoire, Germ.) Any salicyl compound in which the acid constituent is acetic acid. All acetates are soluble in water: the least soluble being the acetates of tungsten, molybdenum, silver, and mercury. The acetates, especially those of lead and aluminium, are of great importance to the arts. The acetates are all described under their respective bases; —a rule which will be adopted with all the acids.

ACETIC ACID. (Acide acétique, Fr.; Essignoire, Germ.; Acidi aceticium, Lat.; Essel, Sax.) The word “acetic” is derived from the Latin acetum, applied to vinegar; probably the earliest known body possessing the sour taste and other properties which characterize acids; hence the term Aceto, now become generic; both the Latin word, and also the Saxon acid from the root acet (Greek akos), an edge or point, in reference to the sharpness of the taste.

Acetic acid is produced either by the oxidation, or the destructive distillation, of organic bodies containing its elements—carbon, hydrogen, and oxygen.

The oxidation of organic bodies, in order to convert them into acetic acid, may be effected either:—1, by exposing them in a finely divided state to the action of air or oxygen gas; 2, by submitting them to the action of ferments, in the presence of a free supply of atmospheric air; or, 3, by the action of chemical oxidizing agents.

When acetic acid is procured by the oxidation of organic bodies, it is generally alcohol that is employed; but by whatever process alcohol is transformed into acetic acid, it is always first converted into an intermediate compound, aldehyde; and this being a very volatile body, it is desirable always to effect the oxidation as completely and rapidly as possible, to avoid the loss of alcohol by the evaporation of this aldehyde.

Alcohol contains C₄ H₆ O₂
Aldehyde " C₄ H₄ O₂
Acetic acid " C₄ H₄ O₄

The process, therefore, consists first in the removal of two equivalents of hydrogen from alcohol, which are converted into water,—aldehyde being produced,—and then the further union of this aldehyde with two equivalents of oxygen to convert it into acetic acid. See ALDEHYDE.

By the oxidation of alcohol, pure acetic acid is obtained: but the vinegars of commerce are mixtures of the pure acetic acid with water; with saccharine, gummin, and coloring matters; with certain ethers (especially the acetic ether), upon which their agreeable aromatic flavor depends; with empyreumatic oils, &c.

The pure acetic acid (free from water and other impurities) may be obtained most advantageously, according to Melsens*, by distilling pure acetate of potash with an excess of acetic acid (which has been obtained by the redistillation of ordinary acetic acid, procured either by oxidizing alcohol, or by the destructive distillation of wood): the acid which first passes over contains water; but finally it is obtained free.

Properties of pure Acetic Acid.—When absolutely pure, acetic acid is a colorless liquid of specific gravity 1·061, which at temperatures below 62° F. (17° C.) solidifies into a colorless crystalline mass. It has strongly acid properties, being as powerfully corrosive as many mineral acids, causing vesication when applied to the skin; and it possesses a peculiar pungent, though not a disagreeable smell.

The vapor of the boiling acid is highly combustible, and burns with a blue flame. Hydrated acetic acid dissolves camphor, gialidine, resins, the fibrine of blood, and several organic compounds. When its vapor is conducted through a slightly ignited porcelain tube, it is converted entirely into carbonic acid and acetone, an atom of the acid being resolved into an atom of each of the resultants. At a white heat the acid vapor is converted into carbonic acid, carburetted hydrogen, and water.

It attracts water with great avidity, mixing with it in all proportions. Its solution in water increases in density with the increase of acetic acid up to a certain point; but beyond this point its density again diminishes. Its maximum density being 1·073, and corresponding to an acid containing C₄ H₄ O₄ + 2Aq., which may be extemporaneously produced by mixing 77·2 parts of crystallized acetic acid with 22·8 parts of water. This hydrate boils at 104° C. (210° F.), whilst the crystallized acid boils only at 120° C. (248° F.);[1]

* Comptes rendus, xix. 611. † Gouard, Chimie Organique, i. 718.
ACETIC ACID.

The proportion of acetic acid in aqueous mixtures may therefore be ascertained, within certain limits, by determination of the specific gravity. See Acetimetry.

The following table, by Mohr, indicates the percentage of acetic acid in mixtures of different specific gravities; but of course this is only applicable in cases where no sugar or other bodies are present, which increase the specific gravity.

Abstract of Mohr's Table of the Specific Gravity of Mixtures of Acetic Acid and Water.*

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<td>45</td>
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<td>95</td>
<td>1.070</td>
<td>40</td>
<td>1.051</td>
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<td>35</td>
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<td>5</td>
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<td>1.064</td>
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<td>1.001</td>
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<tr>
<td>50</td>
<td>1.060</td>
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Which numbers closely agree with those obtained by Dr. Ure. See vol. i. p. 5.

Acetic acid was formerly (and is still by some chemists) viewed as the hydrated teroxide of a radical acetyl, now called vinyl. See Chemical Formula.

\[(\text{C}_2\text{H}_4\text{O}_2)\text{O}_\text{H}\]

Acetyl.

And therefore an anhydrous acetic acid, C₂H₄O₂, is supposed to exist. Many attempts have been made to isolate this anhydrous acetic acid C₂H₄O₂; and a body which has received this name has been quite recently obtained by Gerhardt†, by the double decomposition of chloride of acetyland an alkaline acetate, thus:

\[
\begin{align*}
\text{C}_2\text{H}_4\text{O}_2(\text{O}_\text{Cl}) + \text{K}_2\text{C}_2\text{H}_4\text{O}_2 & = \text{C}_2\text{H}_4\text{O}_4 + \text{K}_2\text{Cl} \\
\text{Chloride of acetyl.} & \quad \text{Acetate of potash.} \quad \text{(So-called) Chloride of anhydrous potassium.}
\end{align*}
\]

acetic acid.

This body Gerhardt describes as a colorless liquid having a strong smell of acetic acid, but associated with the flavor of hawthorne blossom, having a specific gravity of 1.073, and boiling at 137° C. (278° F.); falling in water in the form of oily drops, only dissolving on gently heating that fluid. It is, however, not anhydrous acetic acid, but a compound isomeric with the hypothetical anhydrous acetic acid C₂H₄O₂, containing, in fact, double the amount of matter, its formula being C₂H₄O₃.

The impure varieties of acetic acid known as vinegar, pyrologinous acid, &c., are the products met with in commerce, and therefore those require more minute description in this work.

Before describing the manufacture of these commercial articles, it may be interesting to allude to a method of oxidizing alcohol by means of spongy platinum; which may yet meet with extensive practical application. It is a well-known fact that spongy platinum (e. g. platinum black), from its minute state of division, condenses the oxygen of the air within its pores; consequently, when the vapor of alcohol comes in contact with this body, a supply of oxygen in a concentrated state is presented to it, and the platinum, without losing any of its properties, effects the combination between the oxygen and the alcohol, converting the latter into acetic acid.

This may be illustrated by a very simple experiment. Place recently ignited spongy platinum, loosely distributed on a platinum-gauze, at a short distance over a burner containing warm alcohol, the whole standing under a bell-glass supported by wedges on a glass dish, so that, on removing the stopper from the bell-glass, a slow current of air circulates through the apparatus; the spongy platinum soon begins to glow, in consequence of the combustion going on upon its surface, and acetic acid vapors are abundantly produced, which

† Comptes rendus, xxxiv. 765.
condense and run down the sides of the glass. The simultaneous formation of aldehyde is, at the same time, abundantly proved by its peculiar odor.

In Germany this method has been actually carried out on the large scale, and, if it were not for the high price of platinum, and the heavy duty on alcohol, it might be extensively employed in this country, on account of its elegance and extreme simplicity.

Manufacture of Vinegar by Acetous Fermentation.—All liquids which are susceptible of the vinous fermentation are capable of yielding vinegar. A solution of sugar is the essential ingredient, which is converted first into alcohol, and subsequently into acetic acid. The liquids employed vary according to circumstances. In this country the vinegar of commerce is obtained from an infusion of malt, and in wine countries from inferior wines.

The oxidation of alcohol is remarkably facilitated by the presence of nitrogenized organic bodies in a state of change, called ferments, hence the process is frequently termed acetous fermentation. Now, although in most cases the presence of these ferments curiously promotes the process, yet they have no specific action of this kind; for we have already seen that, by exposure to air in a condensed state, alcohol, even when pure, is converted into acetic acid; and, moreover, the action of oxidizing agents, such as chronic and nitric acid, &c., is capable of effecting this change.

However, in the presence of a ferment, with a free supply of air, and at a temperature of from 60° to 90° F., alcohol is abundantly converted into acetic acid. At the same time that the alcohol is converted into acetic acid, the nitrogenized and other organic matters undergo peculiar changes, and often a white gelatinous mass is deposited,—which contains Vibiones and other of the lower forms of organized beings,—and which has received the name of mother of vinegar," from the supposition that the formation and development of this body, instead of being a secondary result of the process, was really its exciting cause.

Wine vinegar is of two kinds, white and red, according as it is prepared from white or red wine. White wine vinegar is usually preferred, and that made at Orleans is regarded as the best. Dr. Ure found its average specific gravity to be 1·019, and to contain from 64 to 7 per cent. of real acid; according to the Edinburgh Pharmacopoeia, its specific gravity varies from 1·014 to 1·022.

1. Malt Vinegar. (British Vinegar; in Germany called Malz-Getreide or Bieressig.) In England vinegar is chiefly made from an infusion of malt, by first exciting it in the alcoholic fermentation, and subsequently inducing the oxidation of the alcohol into acetic acid.

The transformation of the fermented wort into vinegar was formerly effected in two ways, which were entirely opposite in their manner of operation. In one case the casks containing the fermented malt infusion (or gyle) were placed in close rooms, maintained at a uniform temperature; in the other, they were arranged in rows in an open field, where they remained many months. As regards the convenience and interests of the manufacturer, it appears that each method had its respective advantages, but both are now almost entirely abandoned for the more modern processes to be described—a short notice of the fielding process is, however, retained.

When fielding is resorted to, it must be commenced in the spring months, and then left to complete itself during the warm season. The fielding method requires a much larger extent of space and utensils than the stoving process. The casks are placed in several parallel tiers, with their bung side upwards and left open. Beneath some of the paths which separate the rows of casks are pipes communicating with the "back" at the top of the brewhouse; and in the centre of each is a valve, opening into a concealed pipe. When the casks are about to be filled, a flexible hose is screwed on to this opening, the other end being inserted into the bung-hole of the cask, and the liquor in the "gyle back" at the brewhouse, by its hydrostatic pressure, flows through the underlying pipe and hose into the cask. The hose is so long as to admit of reaching all the casks in the same row, and is guided by a workman.

After some months the vinegar is made, and is drawn off by the following operation:—A long trough or sluce is laid by the side of one of the rows of casks, into which the vinegar is transferred by means of a syphon, whose shorter limb is inserted into the bung-hole of the cask. The trough inclines a little from one end to the other, and its lower end rests on a kind of travelling tank or cistern, wherein the vinegar from several casks is collected. A hose descends from the tank to the open valve of an underground pipe, which terminates in one of the buildings or stores, and, by the agency of a steam boiler and machinery, the pipe is exhausted of its air, and this causes the vinegar to flow through the hose into the valve of the pipe, and thence into the factory buildings. By this arrangement the whole of the vinegar is speedily drawn off. From the storehouse, where the vinegar is received, it is pumped into the refining or rape vessels.

* This substance has been supposed by some to be a fungus, and has been described by Mulder under the name of Mycesedera Aceti.
ACETIC ACID.

These large vessels are generally filled with the stalks and skins of grapes or raisins, (the refuse of the British wine manufacturer is generally used,) and the liquor being admitted at the top, is allowed slowly to filter through them; after passing through, it is pumped up again to the top, and this process is repeated until the acetification is complete. Sometimes wood shavings, straw, or spent tan, are substituted for the grape refuse, but the latter is generally preferred.

By this process, not only is the oxidation of the alcohol completed, but coagulable nitrogenous and mucilaginous matter is separated, and thus the vinegar rendered bright. It is finally pumped into store vats, where it is kept until put into casks for sale.

2. SUGAR, CIDER, FRUIT, AND BEET VINEGARS. An excellent vinegar may be made for domestic purposes by adding, to a syrup consisting of one pound and a quarter of sugar for every gallon of water, a quarter of a pint of good yeast. The liquor being maintained at a heat of from 75° to 90° F., acetification will proceed so well that in 2 or 3 days it may be racked off from the sediment into the ripening cask, where it is to be mixed with 1 oz. of cream of tartar and 1 oz. of crushed raisins. When completely freed from the sweet taste, it should be drawn off clear into bottles, and closely corked up. The juices of currants, gooseberries, and many other indigenous fruits, may be acetified either alone or in combination with syrup. Vinegar made by the above process from sugar should have fully the Revenue strength. It will keep much better than malt vinegar, on account of the absence of gluten, and at the present low price of sugar will cost more, when fined upon beech chips, than 1s. per gallon.

The sugar solution may likewise be replaced by honey, cider, or any other alcoholic or saccharine liquid. An endless number of prescriptions exist, of which the following example may suffice:—100 parts of water to 13 of brandy, 4 of honey, and 1 of tartar.

Messrs. Neale and Duvey, of London, patented a process, in 1841, for the manufacture of vinegar from beet-root.

The saccharine juice is pressed out of the beet, previously mashed to a pulp, then mixed with water and boiled; this solution is fermented with yeast, and finally acetified in the usual way, the process being accelerated by blowing air up through the liquid, which is placed in a cylindrical vessel with fine holes at the bottom.

In some factories large quantities of sour ale and beer are converted into vinegar; but it is usually of an inferior quality, in consequence of being liable to further fermentation. Dr. Stenhouse has shown that when sea-weed is subjected to fermentation at a temperature of 95° F., in the presence of lime, acetate of lime is formed, from which acetic acid may be liberated by the processes described under the head of Pyroglucinous Acid. Although such large quantities of sea-weed are found on all our coasts, it does not yet appear that they have yet been utilized in this way, although they would still be, to a certain extent, valuable as manure after having been subjected to this process.

3. THE GERMAN OR QUICK-VINEGAR PROCESS. (Schmelzessigbereitung.)—In the manufacture of vinegar it is highly important that as free a supply of air should be admitted to the liquid as possible, since, if the oxidation take place but slowly, a considerable loss may be sustained, from much of the alcohol, instead of being completely oxidized to acetic acid, being only converted into aldehyde, which, on account of its volatility, passes off in the state of vapor. This is secured in the German process by greatly enlarging the surface exposed to the air; which, however, not only diminishes or prevents the formation of aldehyde, but also greatly curtails the time necessary for the whole process. In fact, when this method was first introduced, from the supply of air being insufficient, very great loss was sustained from this cause, which was, however, easily remedied by increasing the number of air-holes in the apparatus.

This quick-vinegar process consists in passing the fermented liquor (which generally contains about 50 gallons of brandy of 60 per cent., and 37 gallons of beer or maltwort, with 1/10 of ferment) two or three times through an apparatus called the Vinegar Generator (Essigbildner). See GENERATOR, vol. I.

The analogy between acetification and ordinary processes of decay, and even combustion, is well seen in this process; for, as the oxidation proceeds, the temperature of the liquid rises to 100° or even 104° F.; but if the temperature generated by the process itself be not sufficient, the temperature of the room in which the tanks are placed should be artificially raised.

By this method 150 gallons of vinegar can be manufactured daily in ten tanks, which one man can superintend; and the vinegar, in purity and clearness, resembles distilled vinegar. It is better to avoid using liquors containing much suspended mucilaginous matter, which, collecting on the chips, quickly choke up the apparatus, and not only impedes the process, but contaminates the product.

The chips and shavings may with advantage be replaced by charcoal in fragments, which, by the oxygen it contains condensed in its pores, still further accelerates the process. The charcoal would, of course, require re-igniting from time to time.

By destructive Distillation of Wood. Pyroglucinous Acid.—The general nature of the
process of destructive distillation will be found detailed under the head of Distillation, Destructive; as well as a list of products of the rearrangement of the molecules of organic bodies under the influence of heat in closed vessels. We shall, therefore, at once proceed to the details of the process as specially applied in the manufacture of acetic acid from wood.

The forms of apparatus very generally employed on the continent for obtaining at the same time crude acetic acid, charcoal, and tar, are those of Schwartz and Reichenbach; but in France the process is carried out with special reference to the production of acetic acid alone.

Since the carbonizers of Reichenbach and Schwartz are employed with special reference to the manufacture of wood charcoal, the condensation of the volatile products being only a secondary consideration, they will be more appropriately described under the head of Charcoal.

In England the distillation is generally carried out in large iron retorts, placed horizontally in the furnace, the process, in fact, closely resembling the distillation of coal in the manufacture of coal gas, excepting that the retorts are generally larger, being sometimes 4 feet in diameter, and 6 or 8 feet long. Generally two, or even three, are placed in each furnace, as shown in fig. 1, so that the fire of the single furnace, $s$, plays all round them. The doors for charging the retorts are at one end, b, (fig. 2), and the pipe for carrying off the volatile products at the other, c, by which they are conducted, first to the tar-condenser, d, and finally through a worm in a large tub, e, where the crude acetic acid is collected.

Of course, in different localities an endless variety of modifications of the process are employed.

In the Forest of Dean, instead of cylindrical retorts, square sheet-iron boxes are used, 4 ft. 6 in. by 2 ft. 9 in., which are heated in large square ovens.

With regard to the relative advantages of cylindrical retorts or square boxes, it should be remarked that the cylinders are more adapted for the distillation of the large billets of Gloucestershire, and the refuse ship timber of Glasgow, Newcastle, and Liverpool; but, on the other hand, where light wood is used, such as that generally carbonized in the Welsh factories, the square ovens answer better.

The most recent and ingenious improvement in the manufacture of pyroligneous acid is that patented by the late Mr. A. G. Halliday, of Manchester, and adopted by several large manufacturers. The process consists in effecting the destructive distillation of waste materials, such as saw-dust and spent dye-woods, by causing them to pass in continuous motion through heated retorts. For this purpose the materials, which are almost in a state of powder, are introduced into a hopper, n (fig. 3), whence they descend into the retort, n,
being kept all the while in constant agitation, and at the same time moved forward to the other end of the retort by means of an endless screw, s. By the time they arrive there, the charge has been completely carbonized, and all the pyroligneous acid evolved at the exit tube, t. The residuary charcoal falls through the pipe p into a vessel of water, x, whilst the volatile products escape at y, and are condensed in the usual way.

Several of these retorts are generally set in a furnace side by side, the retorts are only 14 inches in diameter, and eight of these retorts produce in 24 hours as much acid as 16 retorts 3 feet in diameter upon the old system. In the manufacturing districts of Lancashire and Yorkshire, where such immense quantities of spent dye-woods accumulate, and have proved a source of annoyance and expense for their removal, this process has afforded a most important means of economically converting them into valuable products—charcoal and acetic acid.

Mention should also be made of Messrs. Solomons and Azulay's patent for employing superheated steam to effect the carbonization of the wood, which is passed directly into the mass of materials. Since the steam accompanies the volatile products, it necessarily dilutes the acid; but this is in a great degree compensated for by employing these vapors to concentrate the distilled products, by causing them to traverse a coil of tubing placed in a pan of the distillates.

As regards the yield of acetic acid from the different kinds of wood, some valuable facts have been collected and tabulated by Stolze, in his work on Pyroligneous Acid:

<table>
<thead>
<tr>
<th>One Pound of Wood</th>
<th>Weight of Acid</th>
<th>Carbonate of Potassa neutralized by One Ounce of Acid</th>
<th>Weight of Charcoal</th>
</tr>
</thead>
<tbody>
<tr>
<td>White birch</td>
<td>7</td>
<td>55</td>
<td>3½</td>
</tr>
<tr>
<td>Red birch</td>
<td>7</td>
<td>54</td>
<td>3½</td>
</tr>
<tr>
<td>Large-leaved linden</td>
<td>7</td>
<td>52</td>
<td>3½</td>
</tr>
<tr>
<td>Oak</td>
<td>6</td>
<td>50</td>
<td>4½</td>
</tr>
<tr>
<td>Ash</td>
<td>6</td>
<td>44</td>
<td>4½</td>
</tr>
<tr>
<td>Horse chestnut</td>
<td>7</td>
<td>41</td>
<td>4½</td>
</tr>
<tr>
<td>Lombardy poplar</td>
<td>7</td>
<td>40</td>
<td>3½</td>
</tr>
<tr>
<td>White poplar</td>
<td>7</td>
<td>39</td>
<td>3½</td>
</tr>
<tr>
<td>Bird cherry</td>
<td>7</td>
<td>37</td>
<td>3½</td>
</tr>
<tr>
<td>Basket willow</td>
<td>7</td>
<td>35</td>
<td>3½</td>
</tr>
<tr>
<td>Buckthorn</td>
<td>7</td>
<td>34</td>
<td>3½</td>
</tr>
<tr>
<td>Logwood</td>
<td>7</td>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>Alder</td>
<td>7</td>
<td>30</td>
<td>2½</td>
</tr>
<tr>
<td>Juniper</td>
<td>7</td>
<td>29</td>
<td>2½</td>
</tr>
<tr>
<td>White fir</td>
<td>7</td>
<td>29</td>
<td>3½</td>
</tr>
<tr>
<td>Common pine</td>
<td>7</td>
<td>28</td>
<td>3½</td>
</tr>
<tr>
<td>Common savine</td>
<td>7</td>
<td>27</td>
<td>3½</td>
</tr>
<tr>
<td>Red fir</td>
<td>6</td>
<td>25</td>
<td>3½</td>
</tr>
</tbody>
</table>
ACETIC ACID.

Properties of the crude Pyroligneous Acid.—The crude pyroligneous acid possesses the properties of acetic acid, combined with those of the pyrogenous bodies with which it is associated. As first obtained, it is black from the large quantity of tar which it holds in solution; and although certain resins are removed by redistillation, yet it is impossible to remove some of the empyreumatic oils by this process, and a special purification is necessary.

In consequence of the presence of cresote, and other antiseptic hydrocarbons, in the crude pyroligneous acid, it possesses, in a very eminent degree, anti-purutene properties. Flesh steeped in it for a few hours may be afterwards dried in the air without corrupting; but it becomes hard, and somewhat leather-like; so that this mode of preservation does not answer well for butcher's meat. Fish are sometimes cured with it.

Purification of Pyroligneous Acid.—This is effected either, 1st, by converting it into an acetate,—acetate of lime or soda,—and then, after the purification of these salts by exposure to heat sufficient to destroy the tar, and repeated recrystallization, liberating the acid again by distilling with a stronger acid, e. g. sulphuric.

Or, 2d, by destroying the pyrogenous impurities by oxidizing agents, such as binoxide of manganese in the presence of sulphuric acid, &c.

The former is the method generally adopted.

After the naphtha has been expelled, the acid liquor is run off into tanks to deposit part of its impurities; it is then syphoned off into another vessel, in which is either milk of lime, quicklime, or chalk; the mixture is boiled for a short time, and then allowed to stand for 24 hours to deposit the excess of lime with any impurities which the latter will carry down with it. The supernatant liquor is then pumped into the evaporating pans.

The evaporation is effected either by the heat of a fire applied beneath the evaporating pans, or more frequently by a coil of pipe in the liquor, through which steam is passed—the liquor being kept constantly stirred, and the impurities which rise to the surface during the process carefully skimmed off.

From time to time, as the evaporation advances, the acetate of lime which separates is removed by ladles, and placed in baskets to drain; and the residual mother liquor is evaporated to dryness. This mass, by ignition, is converted into carbonate of lime and acetone.

If the acetate of lime has been procured by directly saturating the crude acid, it is called brown acetate; if from the acid once purified by redistillation, it is called gray acetate.

From this gray acetate of lime, acetate of soda is now prepared, by adding sulphate of soda to the filtered solution of the acetate of lime. In performing this operation, it is highly important to remember that, for every equivalent of acetate of lime, it is necessary to add two equivalents of sulphate of soda, on account of the formation of a double sulphate of soda and lime. The equation representing the change being:

$$\text{CaO} + \text{C}_2\text{H}_4\text{O}_2 + 2\text{Na}_2\text{SO}_4 = \text{Na}_2\text{O} + \text{C}_2\text{H}_4\text{O}_2 + \text{CaSO}_4.$$

Acetate of lime. \hspace{1cm} Acetate of soda. \hspace{1cm} Double salt.

Or, if sulphuric acid be considered as a bisbasic acid, which this very reaction so strongly justifies:

$$\text{C}_2\text{H}_4\text{O}_2 (\text{Ca}) + \text{Na}_2\text{SO}_4 = \text{C}_2\text{H}_4\text{O}_2 (\text{Na}) + \text{CaSO}_4 + \text{Na}_2\text{SO}_4.$$

Acetate of lime. \hspace{1cm} Sulphate of soda. \hspace{1cm} Acetate of soda. \hspace{1cm} Double salt.

If this point be neglected, and only one equivalent of sulphate of soda be used, one-half of the acetate of lime may escape decomposition, and thus be lost.

After the separation of the double salt, the solution of acetate of soda is drawn off, any impurities allowed to subside, and then concentrated by evaporation until it has a density of 1.3—when the acetate of soda crystallizes out, and may be further purified, if requisite, by another re-solution and re-crystallization. The contents of the mother liquors are converted into acetone and carbonate of soda, as before.

The crystallized acetate of soda is now fused in an iron pot, at a temperature of about 400°, to drive off the water of crystallization, the mass being kept constantly stirred. A stronger heat must not be applied, or we should effect the decomposition of the salt.

For the production of the acetic acid from this salt, a quantity of it is put into a stout copper still, and a deep cavity made in the centre of the mass, into which sulphuric acid of specific gravity 1·84 is poured in the proportion of 35 per cent. of the weight of the salt; the walls of the cavity are thrown in upon the acid, the whole briskly agitated with a wooden spatula. The head of the still is then luted, and connected with the condensing worm, and the distillation carried out at a very gentle heat. The worm should be of silver or porcelain, as also the still head; and even silver solder should be used to connect the joints in the body of the still. The still is now generally heated by a steam "jacket." See Distillation.

The acid which passes over is nearly colorless, and has a specific gravity of 1·05. That
which collects at the latter part of the operation is liable to be somewhat emphrastic, and therefore, before this point is reached, the receiver should be changed; and throughout the entire operation, care should be taken to avoid applying too high a temperature, as the flavor and purity of the acid will invariably suffer.

Any trace of emphysematous may be removed from the acid by digestion with animal charcoal and redistillation.

A considerable portion of this acid crystallizes at a temperature of from 40° to 50° F., constituting what is called glacial acetic acid, which is the compound C₂H₄O₂ (or C₂H₂O₂•HO).

For culinary purposes, pickling, &c., the acid of specific gravity 1'05 is diluted with five times its weight in water, which renders it of the same strength as Revenue proof vinegar.

Several modifications and improvements of this process have recently been introduced, which require to be noticed.

The following process depends upon the difficult solubility of sulphate of soda in strong acetic acids:—100 lbs. of the pulverized salt being put into a hard glazed stoneware receiver, or deep pan, from 35 to 36 lbs. of concentrated sulphuric acid are poured in one stream upon the powder, so as to flow under it. The mixture of the salt and acid is to be made very slowly, in order to moderate the action and the heat generated, as much as possible. After the materials have been in intimate contact for a few hours, the decomposition is effected; sulphate of soda in crystalline grains will collect at the bottom of the vessel and acetic acid the upper portion, partly liquid and partly in crystals. A small portion of pure acetate of lime added to the acid will free it from any remainder of sulphate of soda, leaving only a little acetate in its place; and though a small portion of sulphate of soda may still remain, it is unimportant, whereas the presence of any free sulphuric acid would be very injurious. This is easily detected by evaporating a little of the liquid, at a moderate heat, to dryness, when that mineral acid can be distinguished from the neutral soda sulphate.

This plan of superseding a troublesome distillation, which is due to M. Mollerat, is one of the greatest improvements in this process, and depends upon the insolubility of the sulphate of soda in acetic acid. The sulphate of soda thus recovered, and well drained, serves anew to decompose acetate of lime; so that nothing but this cheap earth is consumed in carrying on the manufacture. To obtain absolutely pure acetic acid, the above acid has to be distilled in a glass retort.

Viellet recommends the use of hydrochloric instead of sulphuric acid for decomposing the acetate.

The following is his description of the details of the process:—

"The crude acetate of lime is separated from the tarry bodies which are deposited on neutralization, and evaporated to about one-half its bulk in an iron pan. Hydrochloric acid is then added until a distinctly acid reaction is produced on cooling; by this means the resinous bodies are separated, and come to the surface of the boiling liquid in a melted state, whence they can be removed by skimming, while the compounds of lime, with creosote, and other volatile bodies, are likewise decomposed, and expelled on further evaporation. From 4 to 6 lbs. of hydrochloric acid for every 33 gallons of wood vinegar is the average quantity required for this purpose. The acetate, having been dried at a high temperature on iron plates, to char and drive off the remainder of the tar and resinous bodies, is then decomposed, by hydrochloric acid, in a still with a copper head and leaden condensing tube. To every 100 lbs. of salt about 90 to 95 lbs. of hydrochloric acid of specific gravity 1'16 are required. The acid comes over at a temperature of from 100° to 120° C. (212° to 248° F.), and is very slightly impregnated with emphysematous products, while a mere cloud is produced in it by nitrate of silver. The specific gravity of the product varies from 1'058 to 1'061, and contains more than 40 per cent. of real acid; but as it is seldom required of this strength, it is well to dilute the 90 parts of hydrochloric acid with 25 parts of water. These proportions then yield from 95 to 100 parts of acetic acid of specific gravity 1'015."

This process is recommended on the score of economy and greater purity of product. The volatile emphysematic bodies are said to be more easily separated by the use of hydrochloric than sulphuric acid; moreover, the chloride of calcium being a more easily fusible salt than the sulphate of lime, or even than the double sulphate of lime and soda, the acetic acid is more freely evolved from the mixture. The resinous bodies also decompose sulphuric acid towards the end of the operation, giving rise to sulphurous acid, sulphured hydrogen, &c., which contaminates the product.

Imperfections and Adulterations.—In order to prevent the putrefactive change which often takes place in vinegar when carelessly prepared by the fermentation of malt wine, &c., it was at one time supposed to be necessary to add a small quantity of sulphuric acid. This notion has long since been shown to be false; nevertheless, since the addition of 1 part of sulphuric acid to 1,000 of vinegar was permitted by an excise regulation, and thus the practice has received legal sanction, it is still continued by many manufacturers. So long as the quantity is retained within these limits, and if pure sulphuric acid be used (great care
ACETOMETRY.

being taken that there is no arsenic present in such oil of vitriol, as is not unfrequently the case in inferior varieties), no danger can come from the habit; but occasionally the quantity is much overpassed by dishonest dealers, of whom it is to be hoped there are but few.

Dr. Ure mentions having found, by analysis, in a sample of vinegar, made by one of the most eminent London manufacturers, with which he supplied the public, no less than 175 grains of the strongest oil of vitriol per gallon, added to vinegar containing only 3 \(\frac{4}{10}\) per cent. of real acetic acid, giving it an apparent strength after all of only 4 per cent., whereas standard commercial vinegar is rated at 5 per cent.

The methods of determining sulphuric acid will be given, once for all, under the head of ACIDOMETRY, and therefore need not be repeated in every case where it occurs; the same remark applies to hydrochloric acid and others.

Hydrochloric acid is rarely intentionally added to vinegar; but it may accidentally be present when the pyroligneous acid has been purified by Vokel's process. It is detected by the precipitate which it gives with solution of nitrate of silver in the presence of nitric acid.

Nitric acid is rarely found in vinegar. For its method of detection, see Nitric Acid.

Wine vinegar generally contains tartaric acid and tartrates; but it is purified from them by distillation.

Sulphurous acid is occasionally met with in pyroligneous acid. This is recognized by its bleaching action on delicate vegetable colors, and by its conversion, under the influence of nitric acid, into sulphuric acid, which is detected by chloride of barium.

Sulphurated hydrogen is detected by acetate of lead giving a black coloration or precipitate.

Metallic Salts.—If care be not taken in constructing the worm of the still of silver or earthenware, distilled acetic acid is frequently contaminated with small quantities of metal from the still, copper, lead, tin, &c. These metals are detected by the addition of sulphurated hydrogen, as is fully discussed under the head of the individual metals. Copper is the most commonly found, and it may be detected in very minute quantities by the blue color which the solution assumes on being supersaturated with ammonia.

It is not uncommon to add to pyroligneous acid, a little coloring matter and acetic ether, to give it the color and flavor of wine or malt vinegar; but this can hardly be called an adulteration.

The presence of the products of acetification of cider may be detected by neutralizing the vinegar with ammonia, and then adding solution of acetate of lime. Tartrate of lime is, of course, precipitated from the wine vinegar, while the poorly malic acid of the cider affords no precipitate with the lime, but may be detected by acetate of lead, by the glistening pearly scales of malate of lead, hardly soluble in the cold.

Acetic acid is extensively employed in the arts, in the manufacture of the various acetates, especially those of alumina and iron, so extensively employed in calico printing as mordants, sugar of lead, &c. It is likewise used in the preparation of varnishes, for dissolving gums and albuminous bodies; in the culinary arts, especially in the manufacture of pickles and other condiments; in medicine, externally, as a local irritant, and internally, to allay fever, &c.

For the treatment in cases of poisoning, we refer to Taylor, Pereira, and other medical authorities.—H. M. W.

ACETOMETRY. Determination of the Strength of Vinegar.—If in vinegars we were dealing with mixtures of pure acetic acid and water, the determination of the density might, to a certain extent, afford a criterion of the strength of the solution; but vinegar, especially that obtained from wine and malt, invariably contains gluton, saccharine, and mucilaginous matters, which increase its density and render this method altogether fallacious.

The only accurate means of determining the strength of vinegar is by ascertaining the quantity of carbonate of soda or potash neutralized by a given weight of the vinegar under examination. This is performed by adding to the vinegar a standard solution of the alkaline carbonate of known strength from a burette, until, after heating to expel the carbonic acid, a solution of litmus previously introduced into the liquid is distinctly reddened.

The details of this process, which is equally applicable to mineral and other organic acids, will be found fully described under the head of ACIDOMETRY.

Roughly, it may be stated that every 53 grains of the pure anhydrous carbonate of soda, or every 69 grains of carbonate of potassa (i.e. one equivalent), correspond to 60 grains of acetic acid (C\(^{4}H_{4}O_{6}\)).

It is obvious that preliminary examinations should be made to ascertain if sulphuric, hydrochloric, or other mineral acids are present; and, if so, their amount determined, otherwise they will be reckoned as acetic acid.

The British malt vinegar is stated in the London Pharmacopoeia to require a draught

* In most cases where, in commercial language, mention is made of real acetic acid, the hypothetical compound C\(^{4}H_{4}O_{6}\) is meant; but it would be better in future always to give the percentage of acetic acid C\(^{4}H_{4}O_{6}\)—for the body C\(^{4}H_{4}O_{6}\) is altogether hypothetical—never having yet been discovered. See the remarks on Anhydrous Acetic Acid at the commencement of this article.—H. M. W.
ACETYL.

(60 grains) of crystallized carbonate of soda (which contains 10 equivalents of water of crystallization) for saturating a fluid ounce, or 4-46 grains; it contains, in fact, from 4-6 to 5 per cent. of real acetic acid.

The same authorities consider that the purified pyroglucose acid should require 87 grains of carbonate of soda for saturating 100 grains of the acid.

Dr. Urquhart suggests the use of the bicarbonate of potash. Its atomic weight, referred to hydrogen as unity, is 100-584, while the atomic weight of acetic acid is 51-363; if we estimate 2 grains of the bicarbonate as equivalent to 1 of the real acid, we shall commit no appreciable error. Hence a solution of the carbonate containing 200 grains in 100 measures will form an acetimeter of the most perfect and convenient kind; for the measures of test liquid expended in saturating any measure—for instance, an ounce or 1,000 grains of acid—will indicate the number of grains of real acetic acid in that quantity. Thus, 1,000 grains of the above proof would require 50 measures of the acetimetric alkaline solution, showing that it contains 50 grains of real acetic acid in 1,000, or 5 per cent.

Although the bicarbonate of potash of the shops is not absolutely constant in composition, yet the method is no doubt accurate enough for all practical purposes.

The acetimetric method employed by the Excise is that recommended by Messrs. J. and P. Taylor,* and consists in estimating the strength of the acid by the specific gravity which it acquires when saturated by hydrate of lime. Acids which contains 5 per cent. of real acid is equal in strength to the best malt vinegar, called by the makers No. 24, and is assumed as the standard of vinegar strength, under the denomination of "proof vinegar."† Acid which contains 40 per cent. of real acetic acid is, therefore, in the language of the Revenue, 33 per cent. over proof; it is the strongest acid on which duty is charged by the acetimeter. In the case of vinegars which have not been distilled, an allowance is made for the increase of weight due to the mucilage present; hence, in the acetimeter sold by Bate, a weight, marked m, is provided, and is used in trying such vinegars. As the hydrate of lime employed causes the precipitation of part of the mucilaginous matter in the vinegar, it serves to remove this difficulty to a certain extent. (Pereira.)—H. M. W.

ACETONE. Syn. pyroacetic spirit, nesitic alcohol, pyrogenic ether. C₄H₄O. A volatile fluid usually obtained by the distillation of the acetates of the alkaline earths. It is also obtained in a variety of operations where organic matters are exposed to high temperature. Tartaric and citric acids yield it when distilled. Sugar, gum, or starch, when mixed with lime and distilled, afford acetone. If crude acetate of lime be distilled, the acetone is accompanied by a small quantity of ammonia and traces of methylamine. The latter is due to the nitrogen contained in the wood; the distillate from which was used in the preparation of the acetate of lime. Crude acetone may be purified by redistilling it in a water-bath. A small quantity of slack lime should be added previous to distillation, to combine with any acid that may be present. When pure, it forms a colorless mobile fluid, boiling at 133° F. Its density at 18° is 0-7921, at 32° it is 0-8140. The density of its vapor was found by experiment to be 2-90; theory requires 2-01, supposing six volumes of carbon vapor, twelve volumes of hydrogen, and two volumes of oxygen to be condensed to four volumes. When acetone is procured from acetate of lime, two equivalents of the latter are decomposed, yielding one equivalent of acetone, and two equivalents of carbonate of lime. It has been found that a great number of organic acids, when distilled under similar circumstances, yield bodies bearing the same relation to the parent acid that acetone does to acetic acid: this fact has caused the word acetone to be used of late in a more extended sense than formerly. The word ketone is now generally used to express a neutral substance derived by destructive distillation from an acid, the latter losing the elements of an equivalent of carbonic acid during the decomposition. Theoretical chemists are somewhat divided with regard to the rational formulae of the ketones. An overwhelming weight of evidence has been brought by Gerhardt and his followers, to prove that they should be regarded as aldehydes in which an equivalent of hydrogen is replaced by the radical of an alcohol. Thus common acetone (C₄H₆O) is aldehyde (C₄H₆O[H]), in which one equivalent of hydrogen is replaced by methyl, C₂H₅.

Acetone dissolves several gums and resins, amongst others sandarac. Wood spirit, which sometimes, owing to the presence of impurities, refuses to dissolve sandarac, may be made to do so by the addition of a small quantity of acetone.

When treated with sulphuric acid and distilled, acetone yields a hydrocarbon called mesitylene or tropolone, C₆H₆O. G. W.

ACETYL. Two radicals are known by this name, namely, C₂H₄ and C₂H₄O². Their nomenclature has not, as yet, been definitely settled. Dr. Williamson proposes to call it ethyl. The hydrocarbon C₂H₄ is now assumed to exist in aldehyde, which can be regarded as formed on the type two atoms of water, thus:—

\[ \text{C}_2\text{H}_4 \]

In the above formula we have two atoms of water, in which 1 equivalent of hydrogen is

* Quarterly Journal of Science, xii, 255.
† 58 Geo. III. c. 65.
ACID.

replaced by the non-oxidized radical C\(_2\)H\(_3\), which may very conveniently be named aldehyde.—C. G. W.

ACID. (Acidus, sour, L.) The term acid was formerly applied to bodies which were sour to the taste, and in popular language the word is still so used. It is to be regretted that the sciences have led to the extension of this word to any bodies combining with bases to form salts, whether such combining body is sour or otherwise. Had not the term acid been established in language as expressing a sour body, there would have been no objection to its use; but chemists now apply the term to substances which are not sour, and which do not change blue vegetable colors; and consequently they fail to convey a correct idea to the popular mind.

Hobbes, in his "Computation or Logic," says, "A name is a word taken at pleasure to serve for a mark which may raise in our mind a thought like to some thought we had before, and which, being pronounced to others, may be to them a sign of what thought the speaker had, or had not, before in his mind." This philosopher thus truly expresses the purpose of a name; and this purpose is not fulfilled by the term acid, as now employed.

Mr. John Stuart Mill, in his "System of Logic," thus, as it appears not very happily, endeavors to show that the term acid, as a scientific term, is not inappropriate or incorrect.

"Scientific definitions, whether they are definitions of scientific terms or of common terms used in a scientific sense, are almost always of the kind last spoken of; their main purpose is to serve as the landmarks of scientific classification. And, since the classifications in any science are continually modified as scientific knowledge advances, the definitions in the sciences are also constantly varying. A striking instance is afforded by the words acid and alkali, especially the former. As experimental discovery advanced, the substances classed with acids have been constantly multiplying; and, by a natural consequence, the attributes connoted by the word have receded and become fewer. As at first it connoted the attributes of combining with an alkali to form a neutral substance (called a salt), being compounded of a base and oxygen, causticity to the taste and touch, fluidity, &c. The true analysis of muriatic acid into chlorine and hydrogen caused the second property, composition from a base and oxygen, to be excluded from the connotation. The same discovery fixed the attention of chemists upon hydrogen as an important element in acids; and more recent discoveries having led to the recognition of its presence in sulphuric, nitric, and many other acids, where its existence was not previously suspected, there is now a tendency to include the presence of this element in the connotation of the word. But carbonic acid, silica, sulphurous acid, have no hydrogen in their composition; that property cannot, therefore, be connoted by the term, unless those substances are no longer to be considered acids. Causticity and fluidity have long since been excluded from the characteristics of the class by the inclusion of silica and many other substances in it; and the formation of neutral bodies by combination with alkalis, together with such electro-chemical peculiarities as this is supposed to imply, are now the only differentia which form the fixed connotation of the word acid as a term of chemical science."

The term Alkali, though it is included by Mr. J. S. Mill in connection with acid in his remarks, does not stand, even as a scientific term, in the objective position in which we find acid. Alkali is not, strictly speaking, a common name to which any definite idea is attached. Acid, on the contrary, is a word commonly employed to signify sour. With the immense increase which organic chemistry has given to the number of acids, it does appear necessary, to avoid confusion, that some new arrangement, based on a strictly logical plan, should be adopted. This is, however, a task for a master mind; and possibly we must wait for another generation before such a mind appears among us.

In this Dictionary all the acids named will be found under their respective heads; as Acetic, Nitric, Sulphuric Acids, &c.

ACIDIFIER. Any simple or compound body whose presence is necessary for the production of an acid; as oxygen, chlorine, bromine, iodine, fluoride, sulphur, &c., &c.

ACIDIMETER. An instrument for measuring the strength or quantity of real acid contained in a free state in liquids. The construction of that instrument is founded on the principle that the quantity of real acid present in any sample is proportional to the quantity of alkali which a given weight of it can neutralize. The instrument, like the alkalineter (see Alkalineter), is made to contain 1,000 grains in weight of pure distilled water, and is divided accurately into 100 divisions, each of which therefore represents 10 grains of pure distilled water; but as the specific gravity of the liquids which it serves to measure may be heavier or lighter than pure water, 100 divisions of such liquids are often called 1,000 grains' measure, irrespectively of their weight (specific gravity), and accordingly 10-20, &c., divisions of the acidimeter are spoken of as 100-200, &c., grains' measure; that is to say, as a quantity or measure which, if filled with pure water, would have weighed that number of grains.

ACIDIMETRY. Acidimetry is the name of a chemical process of analysis by means of which the strength of acids—that is to say, the quantity of pure free acid contained in a liquid—can be ascertained or estimated. The principle of the method is based upon Dul-
ton's law of chemical combinations: or, in other words, upon the fact that, in order to produce a complete reaction, a certain definite weight of reagent is required.

If, for example, we take 1 equivalent, or 49 parts in weight, of pure oil of vitriol of specific gravity 1.8485, dilute it (of course within limits) with no matter what quantity of water, and add thereto either soda, potash, magnesia, ammonia, or their carbonates, or in fact any other base, until the acid is neutralized—that is to say, until blue litmus-paper is no longer, or only very faintly, reddened when moistened with a drop of the acid liquid under examination—it will be found that the respective weights of each base required to produce that effect will greatly differ, and that with respect to the bases just mentioned these weights will be as follows:

<table>
<thead>
<tr>
<th>Base</th>
<th>Equivalent Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soda (caustic)</td>
<td>31 parts in weight</td>
</tr>
<tr>
<td>Potash (caustic)</td>
<td>47 parts in weight</td>
</tr>
<tr>
<td>Ammonia</td>
<td>17 parts in weight</td>
</tr>
<tr>
<td>Carbonate of soda</td>
<td>55 parts in weight</td>
</tr>
<tr>
<td>Carbonate of potash</td>
<td>69 parts in weight</td>
</tr>
</tbody>
</table>

This being the case, it is evident that if we wish to ascertain by such a method the quantity of sulphuric acid or of any other acid contained in a liquid, it will be necessary, on the one hand, to weigh or measure accurately a given quantity of that liquid to be examined, and, on the other hand, to dissolve in a known volume of water the weight above mentioned of any one of the bases just alluded to, and to pour that solution gradually into that of the acid until neutralization is obtained; the number of volumes of the basic solution which will have been required for the purpose will evidently indicate the amount in weight of acid which existed in the liquid under examination. Acidimetry is therefore exactly the reverse of alkalmimetry, since in principle it depends on the number of volumes of a solution of a base diluted with water to a definite strength, which are required to neutralize a known weight or measure of the different samples of acids.

The solution containing the known weight of base, and capable therefore of saturating a known weight of acid, is called a "test-liquor," and an aqueous solution of ammonia, of a standard strength, as first proposed by Dr. Ure, affords a most exact and convenient means of effecting the purpose, when gradually poured from a graduated dropping-tube or acidimeter into the sample of acid to be examined.

The strength of the water of ammonia used for the experiment should be so adjusted that 1,000 grains' measure of it (that is, 100 divisions of the alkalmeter) really contain one equivalent (17 grains) of ammonia, and consequently neutralize one equivalent of any one real acid. The specific gravity of the pure water of ammonia employed as a test for that purpose should be exactly 0.992, and when so adjusted, 1,000 grains' measure (100 divisions of the acidimeter) will then neutralize exactly

40 grains, or one equivalent, of sulphuric acid (dry).
49 " " " oil of vitriol, sp. gr. 1.8485.
37.5 " " " hydrochloric acid (gas, dry).
54 " " " nitric acid (dry).
60 " " " crystallized acetic acid.
45 " " " oxalic acid.
150 " " " tartaric acid.
51 " " " acetic acid.

And so forth with the other acids.

A standard liquor of ammonia of that strength becomes, therefore, a universal acidimeter, since the number of measures or divisions used to effect the neutralization of 10 or of 100 grains of any one acid, being multiplied by the atomic weight or equivalent number of the acid under examination, the product, divided by 10 or by 100, will indicate the percentage of real acid contained in the sample; the proportion of free acid being thus determined with precision, even to $\frac{1}{3}$ of a grain, in the course of five minutes, as will be shown presently.

The most convenient method of preparing the standard liquor of ammonia of that specific gravity is by means of a glass bead, not but that specific gravity bottles and hydrometers may, of course, be employed; but Dr. Ure remarks, with reason, that they furnish incomparably more tedious and less delicate means of adjustment. The glass bead, of the gravity which the test-liquor of ammonia should have, floats, of course, in the middle of such a liquor, at the temperature of 60° F.; but if the strength of the liquor becomes attenuated by evaporation, or its temperature increased, the attention of the operator is immediately called to the fact, since the difference of a single degree of heat, or the loss of a single hundredth part of a grain of ammonia per cent., will cause the bead to sink to the bottom—a degree of precision which no hydrometer can rival, and which could not otherwise be obtained, except by the troublesome operation of accurate weighing. Whether the solution remains uniform in strength is best ascertained by introducing into the bottle containing the ammonia test-liquor two glass beads, so adjusted that one, being
very slightly heavier than the liquid, may remain at the bottom; whilst the other, being very slightly lighter, reaches the top, and remains just under the surface as long as the liquor is in the normal state; but when, by the evaporation of some ammonia, the liquor becomes weaker, and consequently its specific gravity greater, the head at the bottom rises towards the surface, in which case a few drops of strong ammonia should be added to restore the balance.

An aqueous solution of ammonia, of the above strength and gravity, being prepared, the acidimetric process is in every way similar to that practised in alkalimetry; that is to say, a known weight, for example, 10 or 100 grams of the sample of acid to be examined are poured into a sufficiently large glass vessel, and diluted, if need be, with water, and a little tincture of litmus is poured into it, in order to impart a distinct red color to it; 100 divisions, or 1,000 grams' measure, of the standard ammonia test-liquor above alluded to, are then poured into the same vessel (which, in the present case, is used as an acidimeter), and the operator proceeds to pour the ammonia test-liquor from the acidimeter into the vessel containing the acid under examination, in the same manner, and with the same precautions used in alkalimetry (see ALKALIMETRY), until the change of color, from red to blue, of the acid liquor in the vessel indicates that the neutralization is complete, and the operation finished.

Let us suppose that 100 grams in weight of a sample of sulphuric acid, for example, have required 61 divisions (610 water-grains measure) of the acidimeter for their complete neutralization, since 100 divisions (that is to say, a whole acidimeter full) of the test-liquor of ammonia are capable of neutralizing exactly 49 grams—one equivalent—of oil of vitriol, of specific gravity, 1·8485, it is clear that the 61 divisions employed will have neutralized 29·99 of that acid, and, consequently, the sample of sulphuric acid examined contained that quantity per cent. of pure oil of vitriol, representing 24·4 per cent. of pure anhydrous sulphuric acid; thus—

Divisions. Oil of Vitriol.

\[
\begin{array}{c|c|c}
100 & 49 & 61 \\
\hline
\end{array}
\]

\[ x = 29·99. \]

Anhydrous Acid.

\[
\begin{array}{c|c|c}
100 & 40 & 61 \\
\hline
\end{array}
\]

\[ x = 24·4. \]

The specific gravity of an acid of that strength is 1·2175.

In the same manner, suppose that 100 grams in weight of hydrochloric acid have required 36 divisions (900 grains' measure) of the acidimeter for their complete neutralization, the equivalent of dry hydrochloric acid gas being 36·5, it is clear that 36 divisions only of the ammonia test-liquor have been employed; the sample operated upon must have contained per cent. a quantity of acid equal to 33·50 of dry hydrochloric acid gas in solution, as shown by the proportion:

Divis. Hydrochloric acid.

\[
\begin{array}{c|c|c}
100 & 36·5 & 90 \\
\hline
\end{array}
\]

\[ x = 32·85. \]

The specific gravity of such a sample would be 1·1646.

Instead of the ammonia test-liquor just alluded to, it is clear that a solution containing one equivalent of any other base—such as, for example, carbonate of soda, or carbonate of potash, caustic lime, &c.—may be used for the purpose of neutralizing the acid under examination. The quantity of these salts required for saturation will of course indicate the quantity of real acid, and, by calculation, the percentage thereof in the sample, thus:—The equivalent of pure carbonate of soda 53, and that of carbonate of potash 69, either of these weights will represent one equivalent, and consequently 49 grains of pure oil of vitriol, 36·5 of dry hydrochloric acid, 60 of crystallized, or 51 of anhydrous acetic acid, and so on. The acidimetric assay is performed as follows:—

If with carbonate of soda, take 530 grains of pure and dry carbonate of soda, obtained by igniting the bicarbonate of that base (see ALKALIMETRY), and dissolve them in 10,000 water grains' measure (1,000 acidimetric divisions) of distilled water. It is evident that each acidimeter full (100 divisions) of such a solution will then correspond to one equivalent of any acid; and accordingly, if the test-liquor of carbonate of soda be poured from the acidimeter into a weighed quantity of any acid, with the same precautions as before, until the neutralization is complete, the number of divisions employed in the operation will, by simple rule of proportion, indicate the quantity of acid present in the sample as before. Pure carbonate of soda is easily obtained by recrystallizing once or twice the crystals of carbonate of soda of commerce, and carefully washing them. By heating them gradually they melt, and at a very low red heat entirely lose their water of crystallization and become converted into pulverulent anhydrous neutral carbonate of soda, which should be kept in well closed bottles.

When carbonate of potash is used, then, since the equivalent of carbonate of potash is 69, the operator should dissolve 690 grains of it in the 10,000 grains of pure distilled water, and the acidimeter being now filled with this test-liquor, the assay is carried on again precisely in the same manner as before. Neutral carbonate of potash for acidimetric use
ACIDIMETRY.

is prepared by heating the bichromate of that base to redness, in order to expel one equivalent of its carbonic acid; the residue left is pure neutral carbonate of potash; and in order to prevent its absorbing moisture, it should be put, whilst still hot, on a slab placed over concentrated sulphuric acid, or chloride of calcium, under a glass bell, and, when sufficiently cool to be handled, transferred to bottles carefully closed.

To adapt the above methods to the French weights and measures, now used also generally by the German chemist, we need only substitute 100 decigrammes for 100 grains, and proceed with the graduation as already described.

A solution of caustic lime in cane sugar has likewise been proposed by M. Pelgot for acidimetric purposes. To prepare such a solution, take pure caustic lime, obtained by heating Carara marble among charcoal in a furnace; when sufficiently roasted to convert it into quicklime, shake it with water, and pour upon the slaked lime as much water as is necessary to produce a milky liquor; put this milky liquor in a bottle, and add thereto, in the cold, a certain quantity of pulverized sugar-candy; close the bottle with a good cork, and shake the whole mass well. After a certain time it will be observed that the milky liquid has become very much clearer, and perhaps quite limpid; filter it, and the filtrate will be of lime for every 100 of sugar employed. The liquor should not be heated, because saccharate of lime is much more soluble in cold than in hot water, and if heat were applied it would become turbid or thick, though on cooling it would become clear again.*

A concentrated solution of lime in sugar being thus obtained, it should now be diluted to such a degree that 1,000 water grains' measure of it may be capable of saturating exactly one equivalent of any acid, which is done as follows:—Take 100 grains of hydrochloric acid of specific gravity 1.1812, that weight of acid contains exactly one equivalent = 36.5 of pure hydrochloric acid gas; on the other hand, fill the acidimeter up to 0 (zero) with the solution of caustic lime in sugar prepared as above said, and pour the contents into the acid until exact neutralization is obtained, which is known by testing with litmus paper in the usual manner already described. If the whole of the 100 divisions of the acidimeter had been required exactly to neutralize the 100 grains' weight of hydrochloric acid of the specific gravity mentioned, it would have been a proof that it was of the right strength; but suppose, on the contrary, that only 50 divisions of the lime solution in the acidimeter have been sufficient for the purpose, it is evident that it is half too strong, or, in other words, one equivalent of lime (=28) is contained in those 50 divisions instead of in 100. Pour, therefore, at once, 50 divisions or measures of that lime-liquor into a glass cylinder accurately divided into 100 divisions, and fill up the remaining 50 divisions with water; stir the whole well, and 100 divisions of the lime-liquor will, of course, now contain as much lime as was contained before in the 50; or, in other words, 100 acidimetric divisions will now contain 1 equivalent of lime, and therefore will be capable of exactly neutralizing 1 equivalent of any acid.

When, however, saccharate of lime is used for the determination of sulphuric acid, it is necessary to dilute it considerably, for otherwise a precipitate of sulphate of lime would be produced. This reagent, moreover, is evidently applicable only to the determination of such acids the lime salts of which are soluble in water.

Instead of a solution of caustic lime in sugar, a clean dry piece of white Carara marble may be used. Suppose, for example, that the acid to be assayed is acetic acid, the instructions given by Brande are as follows:—A clean dry piece of marble is selected and accurately weighed; it is then suspended by a silk thread into a known quantity of the vinegar or acetic acid to be examined, and which is cautiously stirred with a glass rod, so as to mix its parts, but without detaching any splinters from the weighed marble, till the whole of the acid is saturated, and no further action on the marble is observed. The marble is then taken out, washed with distilled water, and weighed; the loss in weight which it has sustained may be considered as equal to the quantity of acetic acid present, since the atomic weight of carbonate of lime (=50) is very nearly the same as that of acetic acid (=46). Such a process, however, is obviously less exact than those already described.

But whichever base is employed to prepare the test-liquor, it is clear that the acid tested with it must be so far pure as not to contain any other free acid than that for which it is tested, for in that case the results arrived at would be perfectly fallacious. Unless, therefore, the operator has reason to know that the acid, the strength of which has to be examined by that process, is genuine of its kind, he must make a qualitative analysis to satisfy himself that it is so; for in the contrary case the acid would not be in a fit state to be submitted to an acidimetric assay.

We shall terminate this article by a description of Liebig's acidimetric method of determining the amount of prussic acid contained in solutions; for example, in medicinal prussic acid, in laurel and bitter almond water, essence of bitter almonds, and eymide of potassium. The process is based upon the following reaction:—When an excess of caustic

* The directions given by M. Violette for the preparation of Saccharate of Lime are as follows:—

Digest in the cold 50 grammes of slaked caustic lime in 1 litre of water containing 100 grammes of sugar.
potash is poured in a solution which contains prussic acid, cyanide of potassium is, of course, formed; and if nitrate of silver be then poured in such a liquor, a precipitate of cyanide of silver is produced, but it is immediately redissolved by shaking, because a double cyanide of silver and of potassium (Ag Cy + K Cy) is formed, which dissolves, without alteration, in the excess of potash employed. The addition of a fresh quantity of nitrate of silver produces again a precipitate which agitation causes to disappear as before; and this reaction is repeated until half the amount of prussic acid present in the liquor has been taken up to produce cyanide of silver, the other half being engaged with the potassium in the formation of a double cyanide of silver and of potassium, as just said. As soon, however, as this point is reached, any new quantity of nitrate of silver poured in the liquor causes the cyanide of potassium to react upon the silver of the nitrate, to produce a permanent precipitate of cyanide of silver, which indicates that the reaction is complete, and that the assay is terminated. The presence of chlorides, far from interfering, is desirable, and a certain quantity of common salt is accordingly added, the reaction of chloride of silver being analogous to that of the cyanide of the same metal.

To determine the strength of prussic acid according to the above process, a test or normal solution should be first prepared, which is as follows:

Since 1 equivalent of nitrate of silver (≡170) represents, as we have seen, 2 equivalents of prussic acid (≡54), dissolve, therefore, 170 grains of pure fused nitrate of silver in 10,000 water-grains' measure of pure water; 1,000 water-grains' measure (1 acidimeter full) of such solution will therefore represent 54 grains of prussic acid; and consequently each acidimetal division 0054 grain of pure prussic acid.

Take now a given weight or measure of the sample of prussic acid, or cyanide of potassium, or laurel, or bitter-almond water, or essence of bitter almonds; dilute it with three or four times its volume of water, add caustic potash until the whole is rendered alkaline, and carefully pour it into it a certain quantity of the normal silver solution from the acidimeter, until a slight precipitate begins to appear which cannot be redissolved by agitation; observe the number of acidimetal divisions of the test silver solution employed, and that number multiplied by 0054 will, of course, indicate the proportion of prussic acid present in the quantity of the sample operated upon.

For such liquids which, like laurel water, contain very little prussic acid, it is advisable to dilute the test silver liquor with nine times its bulk of water; a decimal solution is thus obtained, each acidimetal division of which will only represent 000054 of prussic acid, by which figure the number of divisions employed should then be multiplied.

As the essence of bitter almonds mixed with water is turbid, it is absolutely necessary to add and shake it with a sufficient quantity of water to dissolve the particles of oil to which the tallowiness is due, and render it quite clear.

Instead of an acidimeter, an ordinary balance may be used, as follows:—Take 65 grains of fused nitrate of silver, and dissolve them in 5,927 grains' weight of pure distilled water, making altogether 6,000 grains' weight of test silver solution. Weigh off now in a beaker any quantity, say 100, or, if very weak, 1,000 grains' weight of the sample of prussic acid to be examined, dilute it with three or four times its bulk of water, mix with it a certain quantity of a solution of common salt, and a few drops of caustic potash over and above the quantity necessary to make it alkaline. Pour now carefully into the liquid so prepared a portion of the test solution of silver alluded to, until a turbidity or milking begins to be formed, which does not disappear by agitation, and which indicates that the reaction is complete. Every 300 grains of the test silver solution employed represent 1 grain's weight of pure anhydrous prussic acid.

The rationale of these numbers is evident; since 1 equiv. = 170 of nitrate of silver corresponds to 2 equiv. = 54 of prussic acid; 68 of nitrate of silver correspond to 20 of prussic acid, and consequently 300 of a solution containing 68 of nitrate of silver in 6,000 correspond to 1 of prussic acid, thus:

\[
\begin{align*}
170 & : 54 :: 68 : 20 \\
6,000 & : 20 :: 300 : 1
\end{align*}
\]

Lastly, the strength of prussic acid may also be determined with an ordinary balance by a method proposed by Dr. Ure, which method, however, is much less convenient than that of Liebig: it consists in adding peroxide of mercury, in fine powder, to the liquor which contains prussic acid, until it ceases to be dissolved. As the equivalent of peroxide of mercury = 198, is exactly four times that of prussic acid = 27, the weight of peroxide of mercury employed divided by four will give the quantity of prussic acid present. — A. N.

ACIPENSER. See LINGLASS.

ACONITINE. C₉H₁₄NO₄. A poisonous alkaloid constituting the active principle of the Aconite, Aconitum Napellus. — C. G. W.

ACORNS. The seed of the oak (Quercus). These possess some of the properties of the bark; but in a very diluted degree. Acorns are now rarely used. Pigs are sometimes fed upon them. 306 bushels were imported in 1855.
ACORUS CALAMUS. The common sweet flag. This plant is a native of England, growing abundantly in the rivers of Norfolk; from which county the London market is chiefly supplied. The radix calami aromatica of the shops occurs in flattened pieces about one inch wide, and four or five inches long. It is employed medicinally as an aromatic, and it is said to be used by some distillers to flavor gin. The essential oil (oleum acori calami) of the sweet flag is used by snuff-makers for scenting snuff, and it sometimes enters as one of the aromatic ingredients of aromatic vinegar.—Pereira.

ACROSPIRE. (Plantula, Fr.; Blattkeim, Germ.) The sprout at the end of seeds when they begin to germinate. The name is derived from two Greek words, signifying highest and spire, and has been adopted on account of its spiral form. It is the plum or plumule of modern botanists. Malsters use the name to express the growing of the barley.

ACRYLAMINE or ALLYLAMINE. (C₅H₃ N.) A new alkyloid obtained by Hoffmann and Cahorns, by boiling cyanate of allyl with a strong solution of potash. It boils at about 365°.—C. G. W.

ACTINISM. (From akt./o, a ray; signifying merely the power of a ray, without defining what character of ray is intended.)

As early as 1812, M. Berard (in a communication to the Academy of Sciences, on some observations made by him of the phenomena of solar action) drew attention to the fact that three very distinct sets of physical powers were manifested. Luminous power, Heat-producing power, and Chemical power.

The actual conditions of the sun-burn will be understood by reference to the annexed woodcut, and attention to the following description, fig. 4: a b represents the prismatic spectrum—as obtained by the decomposition of white light by the prism—or Newtonian luminous spectrum, consisting of certain bands of color. Newton determined those rays to be seven in number; red, orange, yellow, green, blue, indigo, and violet; recent re-searches, by Sir John Herschel and others, have proved the existence of two other rays; one, the extreme red or crimson ray e, found at the least refrangible end of the spectrum, the other occurring at the most flangible end, or beyond the violet rays, which is a lavender or gray ray. Beyond this point up to f, Professor Stokes has discovered a new set of rays, which are only brought into view when the light is received upon the surfaces of bodies which possess the property of altering the refrangibility of the rays. Those rays have been called the fluorescent rays, from the circumstance that some of the varieties of Flour Sper exhibit this phenomenon in a remarkable manner. In the engraving (fig. 4), the curved line l from a to e indicates the full extent of the luminous spectrum, the point marked l showing the maximum of illuminating power, which exists in the yellow ray.

Sir William Herschel and Sir Henry Englefield determined, in the first instance, the maximum point for the calorific rays, and Sir John Herschel subsequently confirmed their results, proving that the greatest heat was found below the red ray, and that it gradually diminished in power with the increase of refrangibility in the rays, ceasing entirely in the violet ray. Heat rays have been detected down to the point d, and the curved line h indicates the extent of their action.

Now, if any substance capable of undergoing chemical change be exposed to this spectrum, the result will be found to be such as is represented in the accompanying figure and fig. 5. Over the space upon which the greatest amount of light falls, i. e., the region of the yellow and orange rays l, no chemical change is affected; by prolonged action a slight change is brought about where the red ray falls, r, but from the mean green ray g up to the point f, a certain amount of chemical action is maintained; the maximum of action being in the blue and violet rays a. Thus the curve line (fig. 4) from e to f represents the extent and degree of chemical power as manifested in the solar spectrum. Two maxima are marked a and b, differing widely however in their degree.

ADHESION (sticking together). The union of two surfaces. With the phenomena which are dependent upon bringing two surfaces so closely together that the influence of cohesion is exerted, we have not to deal. In arts and manufactures, adhesion is effected by interposing between the surfaces to be united, some body possessing peculiar properties,
ADIPOSE SUBSTANCE or ADIPOSE TISSUE.

such as gum, plaster, resin, marine or ordinary glue, and various kinds of cement. (See these articles.) In many treatises, there has been a sad confusion between the terms adhesion and cohesion. It is to be regretted that our literature shows a growing carelessness in this respect. Adhesion should be restricted to mean, sticking together by means of some interposed substance; cohesion, the state of union effected by natural attraction.

Not only is adhesion exhibited in works of art or manufacture, we find it very strikingly exhibited in nature. Fragments of rocks which have been shattered by concussion are found to be cemented together by silice, lime, oxide of iron, and the like. We sometimes find portions of stone cemented together by the ores of the metals; and, again, broken parts of mineral lodes are frequently reunited by the earthy minerals.

ADIPOSE SUBSTANCE or ADIPOSE TISSUE. (Tissu grossissant, Fr.) An animal oil, resembling in its essential properties the vegetable oils. During life, it appears to exist in a fluid or semi-fluid state; but in the dead animal, it is frequently found in a solid form, constituting suet, which, when divested of the membrane in which it is contained, is called tallow. See TALLOW, OILS, &c.

ADIT or ADIT LEVEL. The horizontal entrance to a mine; a passage or level driven into the hill-side. The accompanying section gives, for the purpose of distinctness, an exaggerated section of a portion of the subterranean workings of a metaliferous mine. It should be understood that d represents a mineral lode, upon which the shaft, a, has been sunk. At a certain depth from the surface of the hill the miners would be inconvenient by water, consequently a level is driven from the side of the hill, b, through which the water flows off, and through which also the miner can bring out the broken rock, or any ore which he may obtain. Proceeding still deeper, supposing the workings to have commenced, as is commonly the case, at a certain elevation above the sea-level, similar conditions to those described again arising, another level is driven so as to intersect the shaft or shafts, as shown at c. In this case, b would be called the shallow, and c the deep adit. The economy of such works as these is great, saving the cost of expensive pumping machinery, and, in many cases, saving also considerable labor in the removal of ores or other matter from the mine.

ADZE. A cutting instrument; differing from the axe by the edge being placed at nearly right angles to the handle, and being slightly curved up or inflected towards it. The instrument is held in both hands, whilst the operator stands upon his work in a stooping position; the handle being from twenty-four to thirty inches long, and the weight of the blade from two to four pounds. The adze is swung in a circular path almost of the same curvature as the blade, the shoulder-joint being the centre of motion, and the entire arm and tool forming, as it were, one inelastic radius; the tool, therefore, makes a succession of small arcs, and in each blow the arm of the workman is brought in contact with the thigh, which serves as a stop to prevent accident. In course preparatory works, the workman directs his adze through the space between his two feet; he thus surprises us by the quantity of wood removed; in fine works he frequently places his toes over the spot to be wrought, and the adze penetrates two or three inches beneath the sole of the shoe; and he thus surprises us by the apparent danger, yet perfect working of the instrument, which, in the hands of a shipwright in particular, almost rivals the joiner's plane; it is with him the nearly universal paring instrument, and is used upon works in all positions.—Holmgjei.

AERATED WATER. The common commercial name of water artificially impregnated with carboxylic acid.

ÆROLITES. Meteoric stones. It cannot be denied that masses of solid matter have fallen from the atmosphere upon the earth.

It is evident that meteoric stones are of cosmic origin; and the composition, therefore, of such as have been examined, shows us the composition of masses of matter existing beyond the earth. A few analyses of meteoric stones will exhibit the chemical character of these extraordinary masses.

<table>
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<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>89-78</td>
<td>90-88</td>
<td>88-98</td>
<td>86-64</td>
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<tr>
<td>Nickel</td>
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<td>8-45</td>
<td>10-25</td>
<td>10-04</td>
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<td>Cobalt</td>
<td>0-66</td>
<td>0-65</td>
<td></td>
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<tr>
<td>Copper</td>
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<tr>
<td>Tin</td>
<td></td>
<td></td>
<td>0-34</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td></td>
<td></td>
<td>0-10</td>
<td>0-05</td>
</tr>
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</table>

—Brook and Miller.
A meteorite fell at Darwar, in the East Indies, on the 15th of February, 1848, which gave 58.3 per cent. of silicates insoluble in aqua regia; 2.5 of sulphur, 6.76 of nickel, and 22.18 of iron. Another stone from Singhir, near Poma, in the Decean, gave earthy silicate, 19.5; iron, 69.16; and nickel, 4.24. Ehrenberg examined a black hazy rain-water which fell in Ireland on the 15th of April, 1849, and found the black color to consist of minute particles of decayed plants, which had probably been brought by the trade winds, and, floating in clouds of aqueous vapor, had decayed.

AEROSTATION; AERONAUTICS. The ascent into the atmosphere by means of balloons. See Balloons.

AGARIC of the oak: called also surgeon's agarie, spungk, touchedew. A fungus found growing on the oak, birch, willow, and other trees. See Amanita.

AGATE. An instrument used by gold-wire drawers, so called from the agate fixed in the middle of it.

AGATE. (Agate, Fr.; Achat, Gr.; Achates, Lat.) A siliceous mineral; a variegated variety of chalcedony.

This stone is the 'Agran of the Greeks, by whom it was so called after the river in Sicily of that name, whence, according to Theophrastes, agates were first procured. Bochart, with much probability, deduces the name from the Punic and Hebrew, naksad, spotted.

The colors of agate are either arranged in parallel or concentric bands, or assume the form of clouds or spots, or arboreescent and moss-like stains. These colors are due to the presence of metallic oxides, and when indistinct, they are frequently artificially developed or produced. By boiling the colorless stone in oil, and afterwards in sulphuric acid, the oil is absorbed by the more porous layers of the stone; it subsequently becomes carbonized, and thus the contrast of the various colors is heightened. The red varieties, also, are artificially produced by boiling them in a solution of proto-sulphate of iron; after which, upon exposing the stones to heat, peroxide of iron is formed, and thus red bands, or rings, of varying intensities, are produced. Cornellians are this very commonly formed; the coloring matter of the true stone being a peroxide of iron.

Agates never occur in a crystalline form, but in the form of rounded pebbles; they are translucent by transmitted light, but are not transparent, have a wax-like fracture, and they are susceptible of a brilliant polish. Agates are used in the arts for inlaying, and for burnishing gold and silver; they are also made into mortars for chemical purposes; and when cut and polished, they are converted, in considerable quantities, into brooches, bracelets, and other ornamental articles. Agates are brought to this country from Arabia, India, and Oberstein, in Saxony: they are also found in Perthshire, and other parts of Scotland. The Scotch Pebble is a variety of the agate, known by its zig-zag pattern as the Portfication Agate. Agates are found frequently in the amygdaloid rocks of Galgenburg, near Oberstein. They are usually ground into form, cut, and polished, at water-mills in the neighborhood, where a considerable trade in them is carried on. Moss Agate, or Mocha Stone, is a chalcedony, containing within it dendritic or moss-like delineations, of an opaque brownish-yellow color, which are due to oxide of manganese, or of iron.—H. W. B.

Agates are found in the Canton markets, as articles of commerce, in abundance, and of the following varieties:—The white-variegated, called also Mocha Stone, varies from 1 to 6 inches in diameter. The dull, milky agate, not so valuable, occurs in sizes of 1 to 10 inches. Lead-colored agate, sometimes uniform, and sometimes spotted, occurs of large size, and is used for cups and boxes. Flesh-colored. Blood-colored. This is sometimes variegated with pale blue and brown; the blue always surrounds the red; the brown has the tint of horn. Clouded and spotted flesh-colored agate is found subject to many flaws. Red agate, with yellow, is of 1 to 4 inches in diameter. The yellow has various tints. Sometimes the pebbles are 7 inches in length. The yellow agate is used for knife-handles. The pale yellow agate is very scarce; it is called also Leonina, being variegated with white, black, and green, and bearing some resemblance to a lion's skin. Blackish-variegated brown agate, in pieces from 2 to 7 inches in diameter, is very hard, and is cut into seals, buttons, and heads of canes, &c., with natural veins, or fiddlestics colors, sunk into the stone. It appears to be of much value.—Oriental Commerce.

Agate is found sufficiently large to be formed into mortars for chemical purposes.

The royal collection at Dresden contains a table-service of German agate; and at Vienna, in the Imperial cabinet, there is an oval dish, twenty-two inches in length, formed of a single stone.—Davenant.

Agates may be stained artificially by soaking in a solution of nitrate of silver, and afterwards exposing them to the sun. These artificial colors disappear on laying the stone for a night in aquafortis. A knowledge of the practicability of thus staining agates naturally leads to the suspicion of many of the colors being the work, not of nature, but of art.

AIR. The gaseous envelope which surrounds this Earth is emphatically so called; it consists of 78% gases nitrogen and oxygen. About 79 measures of nitrogen, or azote, and 21 of oxygen, with 1/10th of carbonic acid,
constitute the air we breathe. The term air is applied to any permanently gaseous body. And we express different conditions of the air, as good air, bad air, foul air, &c.

AIR-ENGINE. The considerable expansibility of air by heat naturally suggested its use as a motive power long before theoretical investigation demonstrated its actual value. The great advance made during the few last years in our knowledge of the mechanical action of heat, has enabled us to determine with certainty the practical result which may be obtained by the use of any contrivance for employing heat as a prime mover of machinery. We are indebted to Professor Wm. Thomson for the fundamental theorem which decides the economy of any thermo-dynamic engine. It is—that in any perfectly constructed engine the fraction of heat converted into work is equal to the range of temperature from the highest to the lowest point, divided by the highest temperature reckoned from the zero of absolute temperature. Thus, if we have a perfect engine in which the highest temperature is 280° and the lowest 80° F., the fraction of heat converted into force will be \[
\frac{280 - 80}{280 + 460},
\]
or rather more than one quarter. So that, if we use a coal of which one pound in combustion gives out heat equivalent to 10,580,000 foot pounds, such an engine as we have just described would produce work equal to 2,368,105 foot pounds for each pound of coal consumed in the furnace. From the above formula of Professor Thomson, it will appear that the economy of any perfect thermo-dynamic engine depends upon the range of temperature we can obtain in it. And as the lowest temperature is generally nearly constant, being ruled by the temperature of the surface of the earth, it follows that the higher we can raise the highest temperature, the more economical will be the engine. The question is thus reduced to this:—In what class of engine can we practically use the highest temperature? In the steam-engine worked with saturated vapor, the limit is obviously determined by the amount of pressure which can be safely employed. In the steam-engine worked with super-heated vapor—i.e. in which the vapor, after passing from the boiler, receives an additional charge of heat without being allowed to take up more water—and also in the air-engine, the limit will depend upon the temperature at which steam or air acts chemically upon the metals employed, as well as upon the power of the metals themselves to resist the destructive action of heat. It thus appears that the steam-engine worked with superheated steam possesses most of the economical advantages of the air-engine. But when we consider that an air-engine may be made available where a plentiful supply of water cannot be readily obtained, the importance of this kind of thermo-dynamic engine is incontestable. The merit of first introducing a practical air-engine belongs to Mr. Stirling. Mr. Ericsson has subsequently introduced various refinements, such as the respirator—a reticulated mass of metal, which, by its extensive conducting surface, is able, almost instantaneously, to give its own temperature to the air which passes through it. But various practical difficulties attend these refinements, which, at best, only apply to engines worked between particular temperatures. The least complex engine, and that which would probably prove most effectual in practice, is that described in the “Philosophical Transactions,” 1833, Part I. It consists of a pump, which compresses air into a receiver, in which it receives an additional charge of heat; and a cylinder, the piston of which is worked by the heated air as it escapes. The difference between the work produced by the cylinder and that absorbed by the pump constitutes the force of the engine; which, being compared with the heat communicated to the receiver, gives results exactly conformable with the law of Professor Thomson above described.—J. P. J.

Dr. Joule has proposed various engines to be worked at temperatures below redness, which, if no loss occurred by friction or radiation, would realize about one-half the work due to the heat of combustion; or about four times the economical duty which has, as yet, been attained by the most perfect steam-engine.

A detailed account of Ericsson’s Calorific Engine may be useful, especially as a certain amount of success has attended his efforts in applying the expansive power of heat to move machinery. It is stated in Hunt’s “Merchant’s Magazine” that Ericsson’s engines are at work in the foundry of Messrs. Hogg and Delamater, in New York; one engine being of five and another of sixty-horse power. The latter has four cylinders. Two, of seventy-two inches in diameter, stand side by side. Over each of these is placed one much smaller. Within these are pistons exactly fitting their respective cylinders, and so connected, that those within the lower and upper cylinders move together. Under the bottom of each of the lower cylinders a fire is applied, no other furnaces being employed. Neither boilers nor water are used. The lower is called the working cylinder; the upper, the supply cylinder. As the piston in the supply cylinder moves down, valves placed in its top, open, and it becomes filled with cold air. As the piston rises within it, these valves close, and the air within, unable to escape as it came, passes through another set of valves into a receiver, from whence it has to pass into the working cylinder to force up the working piston within it. As it leaves the receiver to perform this duty, it passes through what is called the regenerator, where it becomes heated to about 450°; and upon entering the working cylinder, it is further heated by the supply underneath. For the sake of illustration, merely let
us suppose that the working cylinder contains double the area of the supply cylinder; the cold air which entered the upper cylinder will, therefore, but only half fill the lower one. In the course of its passage to the latter, however, it passes through the regenerator; and as it enters the working cylinder, we will suppose that it has become heated to about 480°, by which it is expanded to double its volume, and with this increased capacity it enters the working cylinder. We will further suppose the area of the piston within the cylinder contain 1,000 square inches, and the area of the piston in the supply cylinder above to contain but 500. The air presses upon this with a mean force, we will suppose, of about eleven pounds to each square inch; or, in other words, with a weight of 5,500 pounds. Upon the surface of the lower piston the heated air is, however, pressing upwards with a like force upon each of its 1,000 square inches; or, in other words, with a force which, after overcoming the weight above, leaves a surplus of 5,000 pounds, if we make no allowance for friction. This surplus furnishes the working power of the engine. It will be seen that after one stroke of its piston is made, it will continue to work with this force so long as sufficient heat is supplied to expand the air in the working cylinder to the extent stated; for, so long as the area of the lower piston is greater than that of the upper and a like pressure is upon every square inch of each, so long will the greater piston push forward the smaller, as a two-pound weight upon one end of a balance will be sure to bear down a one-pound weight placed on the other. We need hardly say, that after the air in the working cylinder has forced up the piston within it, a valve opens; and as it passes out, the pistons, by the force of gravity, descend, and cold air again rushes into and fills the supply cylinder. In this manner the two cylinders are alternately supplied and discharged, causing the pistons to play up and down substantially as they do in the steam-engine.

The regenerator must now be described. It has been stated that atmospheric air is first drawn into the supply cylinder, and that it passes through the regenerator into the working cylinder. The regenerator is composed of wire net, like that used in the manufacture of sieves, placed side by side, until the series attains a thickness of about 12 inches. Through the almost innumerable cells formed by the intersections of the wire, the air must pass on its way to the working cylinder. In passing through these it is so minutely divided that all parts are brought into contact with the wires. Supposing the side of the regenerator nearest the working cylinder is heated to a high temperature, the air, in passing through it, takes up, as we have said, about 450° of the 480° of heat required to double the volume of the air; the additional 30° are communicated by the fire beneath the cylinder.

The air has thus become expanded, it forces the piston upwards; it has done its work —valves open, and the impressions air, heated to 480°, passes from the cylinder and again enters the regenerator, through which it must pass before leaving the machine. It has been said that the side of this instrument nearest the cylinder is kept hot; the other side is kept cool by the action upon it of the air entering in the opposite direction at each up-stroke of the pistons; consequently, as the air from the working cylinder passes out, the wires absorb the heat so effectually, that when it leaves the regenerator it has been robbed of it all, except about 30°.

The regenerator in the 60-horse engine measures 26 inches in height and width, internally. Each disk of wire composing it contains 676 superficial inches, and the net has 10 meshes to the inch. Each superficial inch, therefore, contains 100 meshes, which, multiplied by 676, gives 67,600 meshes in each disk; and, as 200 disks are employed, it follows that the regenerator contains 13,520,000 meshes; and consequently, as there are as many spaces between the disks as there are meshes, we find that the air within it is distributed in about 27,000,000 minute cells. Thence every particle of air, in passing through the regenerator, is brought into very close contact with a surface of metal which heats and cools it alternately. Upon this action of the regenerator, Ericsson's Calorific Engine depends. In its application on the large scale, contemplated in the great Atlantic steamer called the "Ericsson," the result was not satisfactory. We may, however, notwithstanding this result safely predicate, from the investigation of Messrs. Thomson and Joule, that the expansion of air by heat will eventually, in some conditions, take the place of steam as a motive power.

AIR-GUN. This is a weapon in which the elastic force of air is made use of to project the ball. It is so arranged, that in a cavity in the stock of the gun, air can be, by means of a piston, powerfully condensed. Here is a reserved force, which, upon its being relieved from pressure, is at once exerted. When air has been condensed to about $\frac{1}{3}$ of its bulk, it exerts a force which is still very inferior to that of gunpowder. In many other respects the air-gun is but an imperfect weapon, consequently it is rarely employed.

ARIS-O-HYDROGEN BLOWPIPE. A blowpipe in which air is used in the place of oxygen, to combine with and give intensity of heat to a hydrogen flame for the purposes of soldering. See Autogenous Soldering.

ALABASTER. Gypsum, Plaster of Paris (Albâtre, Fr.; Alabaster, Germ.), a sulphate of lime. (See Alabaster, Oriental.) When massive, it is called indifferently alabaster or gypsum; and when in distinct and separate crystals, it is termed selenite. Massive alabas-
ALABASTER, ORIENTAL.

ter occurs in Britain in the new red or keeper marl; in Glamorganshire, on the Bristol Channel; in Leicestershire, at Syston; at Tutbury and near Burton-on-Trent, in Staffordshire; at Chellaston, in Derbyshire; near Droitwich it is associated in the marl with rock salt, in strata respectively 40 and 75 feet in thickness; and at Northwich and elsewhere the red marl is intersected with frequent veins of gypsum. At Tutbury it is quarried in the open air, and at Chellaston in caverns, where it is blasted by gunpowder; at both places it is burned in kilns, and otherwise prepared for the market. It lies in irregular beds in the marl, that at Chellaston being about 30 feet thick. There is, however, reason to suppose that it was not originally deposited along with the marl as sulphate of lime, but rather that calcareous strata, by the access of sulphuric acid and water, have been converted into sulphate of lime,—a circumstance quite consistent with the bulging of the beds of marl with which the gypsum is associated, the line, as a sulphate, occupying more space than it did in its original state as a carbonate. At Tutbury and elsewhere, though it lies on a given general horizon, yet it can scarcely be said to be truly bedded, but rambles among the beds and joints of the marl in numerous films, veins, and layers of fibrous gypsum.

A snow-white alabaster occurs at Volterra, in Tuscany, much used in works of art in Florence and Leghorn. In the Paris basin it occurs as a granular crystalline rock, in the Lower Tertiary rocks, known to geologists as the upper part of the Middle Eocene freshwater strata. It is associated with beds of white and green marls; but in the Thuringewald there is a great mass of sulphate of lime in the Permain strata. It has been sunk through to a depth of 70 feet, and is believed to be metamorphosed magnesian limestone or Zeolite. In the United States this calcareous salt occurs in numerous lenticular masses in marly and sand strata, of that part of the Upper Silurian strata known as the Onondaga salt group. It is extracted for agricultural purposes. For mineralogical character, &c., see GYPSUM.—A. C. B.

The gypsum of our own country is found, in apparently inexhaustible quantities, in the red marl formation in the neighborhood of Derby, and has been worked for many centuries. The great bulk of it is used for making plaster of Paris, and as a manure; and it is the basis of many kinds of cement, patented—as Keene's, Martin's, and others.

To get for these purposes, it is worked by mining underground, and the stone is blasted by gunpowder; but this shaken it so much as to be unfit for working into ornaments, &c.; to procure blocks for which it is necessary to have an open quarry. By removing the superincumbent marl, and laying bare a large surface of the rock, the alabaster being very irregular in form, and jutting out in several parts, allows of its being sawn out in blocks of considerable size, and comparatively sound, (as is illustrated by the large tazza in the Museum of Practical Geology.) This stone, when protected from the action of water, is extremely durable, as may be seen in churches all over the country, where monumental effigies, many centuries old, are now as perfect as the day they were made, excepting, of course, willful injuries; but exposure to rain soon decomposes the stone, and it must be borne in mind that it is perfectly unsuited for garden vases or other out-door work in this country.

In working, it can be sawn up into slabs with toothed saws, and for working moldings and sculptures, fine chisels, rasps, and files are the implements used; the polishing is performed by rubbing it with pieces of sandstone, of various degrees of fineness, and water, until it is quite free from scratches, and then giving a gloss by means of polishing powder (oxide of tin) applied on a piece of cloth, and rubbed with a considerable degree of friction on the stone. This material gives employment in Derby to a good many hands in forming it into useful and ornamental articles, and is commonly called Derbyshire Spar; most of the articles are turned in the lathe, and it works something like very hard wood.

Another kind of gypsum also found in Derbyshire is the fibrous or silky kind; it occurs in thin beds, from one to six inches in depth, and is crystallized in long needle-like fibers; being easily worked, susceptible of a high polish, and quite lustrous, it is used for making necklaces, bracelets, brooches, and such like small articles.—S. H.

ALABASTER, ORIENTAL. Oriental alabaster is a form of stalagmitic or stalactitic carbonate of lime, an Egyptian variety of which is highly esteemed. It is also procured from the Pyrenees, from Chili, and from parts of the United States of America. Ancient quarries are still in existence in the province of Oman, in Algeria.

ALBATA PLATE, a name given to one of the varieties of white metal now so commonly employed. See COPPER, and ALLOYS.

ALBUMIN. The white secrees of dogs. After the hair has been removed from skins, this is used to preserve the softness of them, and prepare them for the tan-pit. Fowls' dung is considered by practical tanners an superior to the dung of dogs, and this is obtained as largely as possible. These excreta may be said to be essentially phosphate of lime and magnesia. We are informed that various artificial comounds which represent chemically, the conditions of those natural ones, have been tried without producing the same good results. It is a reflection on our science, if this is really the case.

ALBUMEN. (Album Ovis.) Albumen is a substance which forms a constituent part
ALCOHOL.

of the animal fluids and solids, and which is also found in the vegetable kingdom. It
exists nearly pure in the white of egg. Albumen consists of—

<table>
<thead>
<tr>
<th>Substance</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>52°22</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>7°29</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>15°7</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1°3</td>
</tr>
<tr>
<td>Oxygen</td>
<td>22°39</td>
</tr>
</tbody>
</table>

Its formula being \( \text{C}_2\text{H}_5\text{O}_2\). Albumen coagulates by heat, as is illustrated in the
boiling of an egg. The salts of tin, bismuth, lead, silver, and mercury form with
albumen white insoluble precipitates; therefore, in cases of poisoning by corrosive sub-
limate, nitrate of silver, or sugar of lead, the white of egg is the best antidote which
can be administered.

Albumen is employed in Photography, \textit{which see}.

We imported the following quantities of albumen:—in 1855, 275 cwts.; in 1856,
382 cwts.

\section*{ALCOHOL. (Alcohol, Fr.; Alkohol, or Weingeist, Germ.) The word alcohol is de-
} 

 derived from the Hebrew word “\textit{kohol},” 7\textsuperscript{v} to paint. The oriental females were and are still in the habit of painting the eyebrows with various pigments; the one generally em-
ployed was a preparation of antimony, and to this the term was generally applied. It
became, however, gradually extended to all substances used for the purpose, and ultimately
to strong spirits, which were employed, probably, as solvents for certain coloring principles.
The term was subsequently exclusively used to designate ardent spirits, and ultimately the
radical or principle upon which their strength depends.

As chemistry advanced, \textit{alcohol}, was found to be a member only of a class of bodies
agreeing with it in general characters; and hence the term is now generic, and we speak of
the various \textit{alcohols}. Of these, \textit{common} or \textit{vinous} alcohol is the best known; and, in
common life, by “\textit{alcoholic liquors},” we invariably mean those containing the original or
vinous alcohol.

When the characters of ordinary alcohol have been stated, allusion will be made to the
class of bodies of which this is the type.

Fermented liquors were known in the most remote ages of antiquity. We read (Gen-
esis ix.) that after the flood “\textit{Noah planted a vineyard, and he drank of the wine and was}
drunk.” Homer, who certainly lived 900 years before the Christian era, also frequently
mentions wine, and notices its effects on the body and mind (Odyssey IX. and XXI.); and
Herodotus tells us that the Egyptians drank a liquor fermented from barley. The period
when fermented liquors were submitted to distillation, so as to obtain “\textit{ardent spirits},” is
shrouded in much obscurity. Raymond Lully\textsuperscript{*} was acquainted with “\textit{spirits of wine},” which
he called \textit{aqua ardens}. The separation of absolute alcohol would appear to have been
first effected about this period (1900), by Arnauld de Villeneuve, a celebrated physician
residing in Montpellier (Gerhardt), and its analysis was first performed by Th. de
Saussoir.\textsuperscript{†}

The preparation of alcohol may be divided into three stages:—

1. The production of a fermented vinous liquor—the Fermentation.

2. The preparation from this of an ardent spirit—the Distillation.

3. The separation from this ardent spirit of the last traces of water—the Rectification.

\section*{Fermentation.} The term “fermentation” is now applied to those mysterious
changes which vegetable (and animal) substances undergo when exposed, at a certain tem-
perature, to contact with organic or even organized bodies in a state of change.

There are several bodies which suffer these metamorphoses, and under the influence of
a great number of different exciting substances, which are termed the “ferments”; more-
over, the resulting products depend greatly upon the temperature at which the change takes
place.

The earliest known and best studied of these processes is the one commonly recognized
as the \textit{vinous} or \textit{alcoholic fermentation}.

In this process solutions containing \textit{sugar}—either the juice of the grape (see \textit{Wine}) or
an infusion of germinated barley, malt, (see \textit{Beer})—are mixed with a suitable quantity of
a ferment; beer or wine yeast is usually employed (see \textit{Yeast}), and the whole maintained
at a temperature of between 70° and 80° F. (21° to 26° C.)

Other bodies in a state of putrefactive decomposition will effect the same result as the
yeast, such as putrid blood, white of egg, &c.

The liquid swells up, a considerable quantity of froth collects on the surface, and an
abundance of gas is disengaged, which is ordinary carbonic acid (CO\textsubscript{2}). The composition
of (pure) alcohol is expressed by the formula \( \text{C}_2\text{H}_5\text{O} \), and it is produced in this process

\textsuperscript{*} Thomson's History of Chemistry, I. 41. (1830.)

\textsuperscript{†} Annales de Chimie, xli. 225.
ALCOHOL.

by the breaking up of an equivalent of grape sugar, \( C_{12}H_{22}O_{11} \), into 4 equivalents of alcohol, 8 of carboamic acid, and 4 of water—

\[
\begin{align*}
C_{12}H_{22}O_{11} & = 4 (C_3H_6O_2) \\
C_3H_6O_2 & = 4 HO \\
C_3 & = O_2 = 8 CO_2
\end{align*}
\]

It is invariably the grape sugar which undergoes this change; if the solution contains cane sugar, the cane sugar is first converted into grape sugar under the influence of the ferment. See Searl.

Much diversity of opinion exists with respect to the office which the ferment performs in this process, since it does not itself yield any of the products. See Fermentation.

The liquid obtained by the vinous fermentation has received different names, according to the source whence the saccharine solution was derived. When procured from the expressed juice of fruits—such as grapes, currants, gooseberries, &c.—the product is denominated wine; from a decoction of malt, ale or beer; from a mixture of honey and water, mead; from apples, cider; from the leaves and small branches of the spruce fir (abies excelsa, &c.), together with sugar or treacle, spruce; from rice, rice beer (which yields the spirit arrack); from cocoanut juice, palm wine.

It is an interesting fact that alcohol is produced in very considerable quantities (in the aggregate) during the raising of bread. The carboamic acid which is generated in the dough, and which during its expulsion raises the bread, is one of the products of the fermentation of the sugar in the flour, under the influence of the yeast added; and of course at the same time the complementary product, alcohol, is generated. As Messrs. Ronalds and Richardson remark: “The enormous amount of bread that is baked in large towns—in London, for instance, 8.3 millions of cwts, yearly—would render the small amount of alcohol contained in it of sufficient importance to be worth collecting, provided this could be done sufficiently cheaply.” In London it has been estimated that in this way about 300,000 gallons of spirits are annually lost; but the cost of collecting it would far exceed its value.

2. Distillation. By the process of distillation, ardent spirits are obtained, which have likewise received different names according to the sources whence the fermented liquor has been derived; viz. that produced by the distillation of wine being called brandy, and in France cognac, or eau de vie; that produced by the distillation of the fermented liquor from sugar and molasses, rum. There are several varieties of spirits made from the fermented liquor procured from the cereals (and especially barley), known according to their peculiar methods of manufacture, flavor, &c.—as whiskey, gin, Hollands—the various compounds and liquors. In India, the spirit obtained from a fermented infusion of rice is called arrack.

3. Rectification; preparation of absolute alcohol. It is impossible by distillation alone to deprive spirit of the whole of the water and other impurities—to obtain, in fact, pure or absolute alcohol.

This is effected by mixing with the liquid obtained after one or two distillations, certain bodies which have a powerful attraction for water. The agents commonly employed for this purpose are quicklime, carbonate of potash, anhydrine sulphate of copper, or chloride of calcium. Perhaps the best adapted for the purpose, especially where large quantities are required, is quicklime; it is powdered, mixed in the retort with the spirit (previously twice distilled), and the neck of the retort being securely closed, the whole left for 24 hours, occasionally shaking; during this period the lime combines with the water, and then on carefully distilling, avoiding to continue the process until the last portions come over, an alcohol is obtained which is free from water. If not quite free, the same process may be again repeated.

In experiments on a small scale, an ordinary glass retort may be employed, heated by a water-bath, and fitted to a Liebig's condenser cooled by ice-water, which passes lastly into a glass receiver, similarly cooled.

Although alcohol of sufficient purity for most practical purposes can be readily obtained, yet the task of procuring absolute alcohol entirely free from a trace of water, is by no means an easy one.

Mr. Drinkwater* effected this by digesting ordinary alcohol of specific gravity .850 at 60° F. for 24 hours with carbonate of potash previously exposed to a red heat; the alcohol was then carefully poured off and mixed in a retort with as much fresh-burnt quicklime as was sufficient to absorb the whole of the alcohol; after digesting for 48 hours, it was slowly

distilled in a water-bath at a temperature of about 180° F. This alcohol was carefully redistilled, and its specific gravity at 60° F. found to be '7047, which closely agrees with that given by Gay-Lussac as the specific gravity of absolute alcohol. He found, moreover, that recently ignited anhydrous sulphate of copper was a less efficient dehydrating agent than quicklime.

Graham recommends that the quantity of lime employed should never exceed three times the weight of the alcohol.

Chloride of calcium is not so well adapted for the purification of alcohol, since the alcohol forms a compound with this salt.

Many other processes have been suggested for depriving alcohol of its water.

A curious process was proposed many years ago by Soemmering,* which is dependent upon the peculiar fact, that whilst water moistens animal tissues, alcohol does not, but tends rather to abstract water from them. If a mixture of alcohol and water be enclosed in an ox bladder, the water gradually traverses the membrane and evaporates, whilst the alcohol does not, and consequently by the loss of water the spirituous solution becomes concentrated.

This process, though an interesting illustration of exosmosis, is not practically applicable to the production of anhydrous alcohol; it is, however, an economical method, and well suited for obtaining alcohol for the preparation of varnishes. Smugglers, who bring spirits into France in bladders hid about their persons, have long known, that although the liquor decreased in bulk, yet it increased in strength; hence the people preferred the article conveyed clandestinely. Prof. Graham ingeniously proposed to concentrate alcohol as follows:

"A large shallow basin is covered, to a small depth, with recently burnt quicklime, in coarse powder, and a smaller basin, containing three or four ounces of commercial alcohol, is made to rest upon the lime; the whole is placed under the low receiver of an air-pump, and the exhaustion continued till the alcohol evinces signs of ebullition. Of the mingled vapors of alcohol and water which now fill the receiver, the quicklime is capable of uniting with the aqueous only, which is therefore rapidly withdrawn, while the alcohol vapor is unaffected; and as water cannot remain in the alcohol as long as the superincumbent atmosphere is devoid of moisture, more aqueous vapor rises, which is likewise abstracted by the lime, and thus the process goes on till the whole of the water in the alcohol is removed. Several days are always required for this purpose.

* Properties of Alcohol.—Absolute.

In the state of purity, alcohol is a colorless liquid, highly inflammable, burning with a pale blue flame, very volatile, and having a density of '0792 at 15°5 C. (60° F.) (Drinkwater.) It boils at 78°4 C. (173° F.) It has never yet been solidified, and the density of its vapor is 1.6133.

Anhydrous alcohol is composed by weight of 52.18 carbon, 13.04 hydrogen, and 34.78 of oxygen. It has for its symbol C*H*O = C*H*O + HO, or hydrated oxide of ethyle. It has a powerful affinity for water, removing the water from moist substances with which it is brought in contact. In consequence of this property, it attracts water from the air, and rapidly becomes weaker, unless kept in very well-stopped vessels. In virtue of its attraction for water, alcohol is very valuable for the preservation of organic substances, and especially of anatomical preparations, in consequence of its causing the coagulation of albuminous substances; and for the same reason it causes death when injected into the veins.

When mixed with water a considerable amount of heat is evolved, and a remarkable contraction of volume is observed; these effects being greatest with 51 per cent. of alcohol and 46 of water, and thence decreasing with a greater proportion of water. For alcohol which contains 90 per cent. of water, this condensation amounts to 1.94 per cent. of the volume; for 80 per cent., 2.87; for 70 per cent., 3.44; for 60 per cent., 5.73; for 40 per cent., 3.44; for 30 per cent., 2.73; for 20 per cent., 1.72; for 10 per cent., 0.72.

Alcohol is prepared absolute for certain purposes, but the mixtures of alcohol and water commonly met with in commerce are of an inferior strength. Those commonly sold are "Rectified Spirit," and "Proof Spirit."

"Proof Spirit" is defined by Act of Parliament, 58 Geo. III. c. 28, to be "such as shall, at the temperature of fifty-one degrees of Fahrenheit's thermometer, weigh exactly twelve-thirteen parts of an equal measure of distilled water." And by very careful experiment, Mr. Drinkwater has determined that this proof spirit has the following composition:—

<table>
<thead>
<tr>
<th>Alcohol and Water</th>
<th>Specific Gravity at 69° F.</th>
<th>Bulk of the mixture of 100 measures of Alcohol, and 81.83 of Water.</th>
</tr>
</thead>
<tbody>
<tr>
<td>By weight.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>108.90</td>
<td>100 + 81.82</td>
</tr>
<tr>
<td>40:100</td>
<td>50.78</td>
<td></td>
</tr>
</tbody>
</table>

In commerce the strength of mixtures of alcohol and water is stated at so many degrees, according to Sykes's hydrometer, above or below proof. This instrument will be explained under the head of Alcoholometry.

As will have been understood by the preceding remarks, the specific gravity or density of mixtures of alcohol and water rises with the diminution of the quantity of alcohol present; or, in other words, with the amount of water. And since the strength of spirits is determined by ascertaining their density, it becomes highly important to determine the precise ratio of this increase. This increase in density, with the amount of water, or diminution with the quantity of alcohol, is, however, not directly proportional, in consequence of the contraction of volume which mixtures of alcohol and water suffer.

It therefore became necessary to determine the density of mixtures of known composition, prepared artificially. This has been done recently with great care by Mr. Drinkwater; and the following table by him is recommended as one of the most accurate:

**Table of the Quantity of Alcohol, by Weight, contained in Mixtures of Alcohol and Water of the following Specific Gravities:**

<table>
<thead>
<tr>
<th>Specific Gravity at 60° F.</th>
<th>Alcohol, per cent. by weight.</th>
<th>Specific Gravity at 60° F.</th>
<th>Alcohol, per cent. by weight.</th>
<th>Specific Gravity at 60° F.</th>
<th>Alcohol, per cent. by weight.</th>
<th>Specific Gravity at 60° F.</th>
<th>Alcohol, per cent. by weight.</th>
<th>Specific Gravity at 60° F.</th>
<th>Alcohol, per cent. by weight.</th>
<th>Specific Gravity at 60° F.</th>
<th>Alcohol, per cent. by weight.</th>
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<td>0.00</td>
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</tbody>
</table>

The preceding table, though very accurate so far as it goes, is not sufficiently extensive for practical purposes, only going, in fact, from 6 to 10 per cent. of alcohol; the table of Tralle's (below) extends to 50 per cent. of absolute alcohol.

Moreover, Drinkwater's table has the (practical) disadvantage (though scientifically more correct and useful) of stating the percentage by weight; whereas, in Tralle's table, it is given by volume. And since liquors are vended by measure, and not by weight, the centesimal amount by volume is usually preferred. But as the bulk of liquids generally, and particularly that of alcohol, is increased by heat, it is necessary that the statement of the density in a certain volume should have reference to some normal temperature. In the construction of Tralle's table the temperature of the liquids was 60° F.; and, of course, in using it, it is necessary that the density should be observed at that temperature.

In order to convert the statement of the composition by volume into the content by weight, it is only necessary to multiply the percentage of alcohol by volume by the specific gravity of absolute alcohol, and then divide by the specific gravity of the liquid.

**Tralle's Table of the Composition, by Volume, of Mixtures of Alcohol and Water of different Densities.**

<table>
<thead>
<tr>
<th>Percentage of Alcohol by volume</th>
<th>Specific Gravity at 60° F.</th>
<th>Difference of the specific gravities.</th>
<th>Percentage of Alcohol by volume</th>
<th>Specific Gravity at 60° F.</th>
<th>Difference of the specific gravities.</th>
<th>Percentage of Alcohol by volume</th>
<th>Specific Gravity at 60° F.</th>
<th>Difference of the specific gravities.</th>
</tr>
</thead>
<tbody>
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<td>0.0056</td>
<td>0.9996</td>
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<td>0.9480</td>
<td>25</td>
<td>94</td>
<td>0.8328</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>0.9679</td>
<td>0.0056</td>
<td>0.9462</td>
<td>25</td>
<td>95</td>
<td>0.8309</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>0.9668</td>
<td>0.0056</td>
<td>0.9444</td>
<td>26</td>
<td>96</td>
<td>0.8290</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>0.9658</td>
<td>0.0056</td>
<td>0.9427</td>
<td>26</td>
<td>97</td>
<td>0.8271</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.9647</td>
<td>0.0056</td>
<td>0.9410</td>
<td>27</td>
<td>98</td>
<td>0.8253</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>0.9634</td>
<td>0.0056</td>
<td>0.9393</td>
<td>27</td>
<td>99</td>
<td>0.8235</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>0.9622</td>
<td>0.0056</td>
<td>0.9377</td>
<td>28</td>
<td>100</td>
<td>0.8218</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>0.9609</td>
<td>0.0056</td>
<td>0.9360</td>
<td>28</td>
<td>100</td>
<td>0.8200</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

In order, however, to employ this table for ascertaining the strength of mixtures of alcohol and water of different densities (which is the practical use of such tables), it is absolutely necessary that the determination of the density should be performed at an inviable temperature,—viz. 60° F. The methods of determining the density will be hereafter described; but it is obvious that practically the experiment cannot be conveniently made at any fixed temperature, but must be performed at that of the atmosphere.
ALCOHOL.

The boiling point of mixtures of alcohol and water likewise differ with the strength of such mixtures.

According to Gay-Lussac, absolute alcohol boils at 78°4 C. (172° F.) under a pressure of 790 millimetres (the millimetre being 0'03937 English inches). When mixed with water, of course its boiling point rises in proportion to the quantity of water present, as is the case in general with mixtures of two fluids of greater and less volatility. A mixture of alcohol and water, however, presents this anomaly, according to Sthenometrius: when the mixture contains less than six per cent. of alcohol, those portions which first pass off are saturated with water, and the alcoholic solution in the retort becomes richer, till absolute alcohol passes over; but when the mixture contains more than six per cent. of water, the boiling point rises, and the quantity of alcohol in the distillate steadily diminishes as the distillation proceeds.

According to Gröning's researches, the following temperatures of the alcoholic vapors correspond to the accompanying contents of alcohol in percentage of volume which are disengaged in the boiling of the spirituous liquid.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fahr. 170°</td>
<td>93</td>
<td>92</td>
<td>Fahr. 189°</td>
<td>71</td>
<td>20</td>
</tr>
<tr>
<td>171°</td>
<td>92</td>
<td>90</td>
<td>180°</td>
<td>62</td>
<td>18</td>
</tr>
<tr>
<td>172°</td>
<td>91</td>
<td>85</td>
<td>190°</td>
<td>61</td>
<td>15</td>
</tr>
<tr>
<td>173°</td>
<td>90</td>
<td>80</td>
<td>200°</td>
<td>61</td>
<td>12</td>
</tr>
<tr>
<td>174°</td>
<td>90</td>
<td>70</td>
<td>210°</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>174°6</td>
<td>89</td>
<td>70</td>
<td>220°</td>
<td>50</td>
<td>7</td>
</tr>
<tr>
<td>176°</td>
<td>87</td>
<td>65</td>
<td>230°</td>
<td>42</td>
<td>5</td>
</tr>
<tr>
<td>178°3</td>
<td>85</td>
<td>50</td>
<td>240°</td>
<td>36</td>
<td>3</td>
</tr>
<tr>
<td>180°8</td>
<td>82</td>
<td>40</td>
<td>250°</td>
<td>28</td>
<td>2</td>
</tr>
<tr>
<td>183°</td>
<td>80</td>
<td>35</td>
<td>260°</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>185°</td>
<td>78</td>
<td>30</td>
<td>270°</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>187°4</td>
<td>76</td>
<td>25</td>
<td>280°</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Gröning undertook this investigation in order to employ the thermometer as an alcoholometer in the distillation of spirits; for which purpose he thrust the bulb of the thermometer through a cork inserted into a tube fixed in the capital of the still. The state of the barometer ought also to be considered in making comparative experiments of this kind. Since, by this method, the alcoholic content may be compared with the temperature of the vapor that passes over at any time, so also, the contents of the whole distillation may be found approximately; and the method serves as a convenient means of making continual observations on the progress of the distillation.

Density of the Vapor.—One volume of alcohol yields 488-3 volumes of vapor at 212° F. The specific gravity of the vapor, taking air as unity, was found by Gay-Lussac to be 1-6183. [Its vapor-density, referred to hydrogen, as unity, is 18'30057.] Spirituous vapor passed through an ignited tube of glass or porcelain is converted into carbonic oxide, water, hydrogen, carburetted hydrogen, olefiant gas, naphthaline, empyreumatic oil, and carbon; according to the degree of heat and nature of the tube, these products vary. Anhydrous alcohol is a non-conductor of electricity, but is decomposed by a powerful voltaic battery. Alcohol burns in the air with a blue flame into carbonic acid and water; the water being heavier than the spirit, because 46 parts of alcohol contain 6 of hydrogen, which form 54 of water. In oxygen the combustion is accompanied with great heat, and this flame, directed through a small tube, powerfully ignites bodies exposed to it.

Platinum in a finely divided state has the property of determining the combination of alcohol with the oxygen of the air in a remarkable manner. A ball of spongy platinum, placed slightly above the wick of a lamp, fed by spirit, and communicating with the wick by a platinum wire, when once heated, keeps at a red heat, gradually burning the spirit. This has been applied in the construction of the so-called "philosophical pastilles;" eau-de-cologne or other perfumed spirit being thus made to diffuse itself in a room.

Mr. Gill has also practically applied this in the construction of an alcohol lamp without flame.

A coil of platinum wire, of about the one-hundredth part of an inch in thickness, is coiled partly round the cotton wick of a spirit lamp, and partly above it, and the lamp lighted to heat the wire to redness; on the flame being extinguished, the alcohol vapor keeps the wire red hot for any length of time, so as to be in constant readiness to ignite a match, for example. This lamp affords sufficient light to show the hour by a watch in the night, with a very small consumption of spirit.
ALCOHOL.

This property of condensing oxygen, and thus causing the union of it with combustible bodies, is not confined to platinum, but is possessed, though in a less degree, by other porous bodies. If we moisten sand in a capsule with absolute alcohol, and cover it with previously heated nickel powder, protoxide of nickel, cobalt powder, protoxide of cobalt, protoxide of uranium, or oxide of tin (these six bodies being procured by ignition of their oxalates in a crucible), or finely powdered peroxyde of manganese, combustion takes place, and continues so long as the spirituous vapor lasts.

*Solvent Power.*—One of the properties of alcohol most valuable in the arts is its solvent power.

It dissolves gases to a very considerable extent, which gases, if they do not enter into combinations with the alcohol, or act chemically upon it, are expelled again on boiling the alcohol. Several salts, especially the deliquescent, are dissolved by it, and some of them give a color to its flame; thus the solutions of the salts of strontia in alcohol burn with a crimson flame, those of copper and borax with a green one, lime a redish, and baryta with a yellow flame.

This solvent power is, however, most remarkable in its action upon resins, ethers, essential oils, fatty bodies, alkaloids, as well as many organic acids. In a similar way it dissolves iodine, bromine, and in small quantities sulphur and phosphorus. In general it may be said to be an excellent solvent for most hydrogenized organic substances.

In consequence of this property it is most extensively used in the chemical arts; e.g., for the solution of gum-resins, &c., in the manufacture of varnishes; in pharmacy, for the separating of the active principles of plants, in the preparation of tinctures. It is also employed in the formation of chloroform, ether, spirits of nitre, &c.

*Methylated Spirit.*—It was, therefore, for a long time a great desideratum for the manufacturer to obtain spirit free from duty. The Government, feeling the necessity for this, have sanctioned the sale of spirit which has been flavored with methyl-alcohol, so as to render it unpalatable, *free of duty* under the name of "methylated spirit." This methylated spirit can now be obtained, in large quantities only, and by giving suitable security to the Board of Inland Revenue of its employment for manufacturing purposes only, and must prove of great value to those manufacturers who are large consumers.

Professors Graham, Hoffman, and Redwood, in their "Report on the Supply of Spirit of Wine, free of duty, for use in the Arts and Manufactures," addressed to the Chairman of the Board of Inland Revenue, came to the following conclusions:

"From the results of this inquiry, it has appeared that means exist by which spirit of wine, produced in the usual way, may be rendered unfit for human consumption, as a beverage, without materially impairing it for the greater number of the more valuable purposes of the arts in which spirit is usually applied. To spirit of wine, of not less strength than corresponds to density 0·830, it is proposed to make an addition of 10 per cent, of purified wood naphtha (wood or methyllic spirit), and to issue this mixed spirit for consumption, duty free, under the name of Methylated Spirit. It has been shown that methylated spirit resists any process for its purification; the removal of the substance added to the spirit of wine being not only difficult, but, to all appearance, impossible; and further, that no danger is to be apprehended of the methylated spirit being ever compounded so as to make it palatable. It may be found safe to reduce eventually the proportion of the mixing ingredient to 5 per cent, or even a smaller proportion, although it has been recommended to begin with the larger proportion of 10 per cent."

And further, the authors justly remark:—"The command of alcohol at a low price is sure to suggest a multitude of improved processes, and of novel applications, which can scarcely be anticipated at the present moment. It will be felt far beyond the limited range of the trades now more immediately concerned in the consumption of spirits; like the repeal of the duty on salt, it will at once most vitally affect the chemical arts, and cannot fail, ultimately, to exert a beneficial influence upon many branches of industry."

And in additional observations, added subsequently to their original report, the chemists above named recommend the following restriction upon the sale of the methylated spirit:—"That the methylated spirit should be issued by agents duly authorized by the Board of Inland Revenue, to none but manufacturers, who should themselves consume it; and that application should always be made for it according to a recognized form, in which, besides the quantity wanted, the applicant should state the use to which it is to be applied, and undertake that it should be applied for that purpose only. The manufacturer might be permitted to retail varnishes and other products containing the methylated spirit, but not the methylated spirit itself, in an unaltered state." They recommend that the methylated spirit should not be made with the ordinary crude, very impure wood naphtha, since this could not be advantageously used as a solvent for resins by hatters and varnish-makers, as the less volatile parts of the naphtha would be retained by the resins after the spirit had evaporated, and the quality of the resin would be thus impaired. If, however, the methylated spirit be originally prepared with the crude wood naphtha, it may be purified by a simple distillation from 10 per cent. of potash.

Vol. III.—3?
It appears that the boon thus afforded to the manufacturing community of obtaining spirit duty free has been acknowledged and appreciated; and now for most purposes, where the small quantity of wood-spirit does not interfere, the methylated spirit is generally used. It appears that even ether and chloroform, which one would expect to derive an unpleasant flavor from the wood-spirit, are now made of a quality quite unobjectionable from the methylated spirit; but care should be taken, especially in the preparation of medicinal compounds, not to extend the employment of the methylated spirit beyond its justifiable limits, lest so useful an article should get into disrepute. Methylated spirit can be procured also in small quantities from the wholesale dealers, containing in solution 1 oz. to the gallon of shellac, under the name of "finish."

**Alcohoholates.**—Graham has shown that alcohol forms crystallizable compounds with several salts. These bodies, which he calls "Alcohoholates," are in general rather unstable combinations, and almost always decomposed by water. Among the best known are the following:

- Alcohoholate of chloride of calcium
- Alcohoholate of chloride of zinc
- Alcohoholate of tin
- Alcohoholate of nitrate of magnesia

<table>
<thead>
<tr>
<th>Compound Name</th>
<th>Molecular Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohoholate of calcium</td>
<td>Ca Cl</td>
</tr>
<tr>
<td>Alcohoholate of zinc</td>
<td>Zn Cl</td>
</tr>
<tr>
<td>Alcohoholate of tin</td>
<td>Sn Cl</td>
</tr>
<tr>
<td>Alcohoholate of nitrate of magnesia</td>
<td>Mg O <em>3</em> NO <em>4</em></td>
</tr>
</tbody>
</table>

**Alcohohometry.** or Alcohohometry. Determination of the Strength of Mixtures of Alcohol and Water. Since the commercial value of the alcoholic liquors, commonly called "spirits," is determined by the amount of pure or absolute alcohol present in them, it is evident that a ready and accurate means of determining this point is of the highest importance to all persons engaged in trade in such articles. If the mixture contain nothing but alcohol and water, it is only necessary to determine the density or specific gravity of such a mixture; if, however, it contain saccharine matters, coloring principles, &c., as is the case with wine, beer, &c., other processes become necessary, which will be fully discussed hereafter.

The determination of the specific gravity of spirit, as of most other liquids, may be effected, with perhaps greater accuracy than by any other process, by means of a stoppered specific gravity bottle. If the bottle be of such a size as exactly to hold 1,000 grains of distilled water at 60° F., it is only necessary to weigh it full of the spirit at the same temperature, when (the weight of the bottle being known) the specific gravity is obtained by a very simple calculation. See Specific Gravity.

This process, though very accurate, is somewhat troublesome, especially to persons unacquainted with accurate chemical experiments, and involves the possession of a delicate balance. The necessity for this is however obviated by the employment of one of the many modifications of the common hydrometer. This is a floating instrument, the use of which depends upon the principle, that a solid body immersed into a fluid is buoyed upwards with a force equal to the weight of the fluid which it displaces, i.e., to its own bulk of the fluid; consequently, the denser the spirituous mixture, or the less alcohol it contains, the higher will the instrument stand in the liquid; and the less dense, or the more spirit it contains, the lower will the apparatus sink into it.

There are two classes of hydrometers: 1st. Those which are always immersed in the fluid to the same depth, and to which weights are added to adjust the instrument to the density of any particular fluid. Of this kind are Fahrenheit's, Nicholson's, and Guyton de Morveau's hydrometers. 2d. Those which are always used with the same weight, but which sink into the liquids to be tried, to different depths, according to the density of the fluid. Of this class are most of the common glass hydrometers, such as Beaumé's, Curtis's, Gay-Lussac's, Twaddle's, &c.

Sykes's and Dica's combine both principles. See Hydrometers.

Syke's hydrometer, or alcoholometer, is the one employed by the Board of Excise, and therefore the one most extensively used in this country. This instrument does not immediately indicate the density or the percentage of absolute alcohol, but the degree above or below proof—the meaning of which has been before detailed; (p. 30.)

It consists of a spherical ball or float, a, with an upper and lower stem of brass, b and c. The upper stem is graduated into ten principal divisions, which are each subdivided into five parts. The lower stem, e, is made conical, and has a loaded bulb at its extremity. There are nine movable weights, numbered respectively by tens from 10 to 90. Each of these circular weights has a slit in it, so that it can be placed on the conical stem, e. The instrument is adjusted so that it floats with the surface of the fluid coincident with zero on the scale in a spirit of specific gravity 625 at 60° F., this being accounted by the Excise as "standard alcohol." In weaker spirit, which has therefore a greater density, the hydrom-

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* Some differences of opinion appear to exist whether Chloroform can be obtained pure from methylated spirit.
ALCOHOLOMETRY.

eter will not sink so low; and if the density be much greater, it will be necessary to add one of the weights to cause the entire immersion of the bulb of the instrument. Each weight represents so many principal divisions of the stem as its number indicates; thus, the heaviest weight, marked 90, is equivalent to 90 divisions of the stem, and the instrument, with the weight added, floats at 0 in distilled water. As each principal division on the stem is divided into five subdivisions, the instrument has a range of 500 degrees between the standard alcohol (specific gravity 839) and water. There is a line on one of the side faces of the stem, b, near division 1 of the drawing, at which line the instrument with the weight 60 attached to it, floats in spirits exactly of the strength of proof, at a temperature of 51° F.

In using this instrument, it is immersed in the spirit, and pressed down by the hand until the whole of the graduated portion of the upper stem is wet. The force of the hand required to sink it will be a guide to the selection of the proper weight. Having taken one of the circular weights necessary for the purpose, it is slipped on to the lower conical stem.

The instrument is again immersed, and pressed down as before to 0, and then allowed to rise and settle at any point. The eye is then brought to the level of the surface of the spirit, and the part of the stem cut by the surface as seen from below, is marked. The number thus indicated by the stem is added to the number of the weight, and the sum of these, together with the temperature of the spirit, observed at the same time by means of a thermometer, enables the operator, by reference to a table which is sold to accompany the instrument, to find the strength of the spirit tested.

These tables are far too voluminous to be quoted here; and this is unnecessary, since the instrument is never sold without them.

A modification of Sykes's hydrometer has been recently adopted for testing alcoholic liquors, which is perhaps more convenient, as the necessity for the loading weights is done away with, the stem being sufficiently long not to require them. It is constructed of glass, and is in the shape of a common hydrometer, the stem being divided into degrees; it carries a small spirit thermometer in the bulb, to which a scale is fixed, ranging from 30° to 82° F. (0 to 12° C). There are tables supplied with the hydrometer, which are headed by the degrees and half degrees of the thermometric scale; and the corresponding content of spirit, over or under proof at the respective degrees of the table, is placed opposite each degree of the hydrometer. See Spirits, vol. ii.

In France, Gay-Lussac's alcoolomètre is usually employed. It is a common glass hydrometer, with the scale on the stem divided into 100 parts or degrees. The lowest division, marked 0, denotes the specific gravity of pure water; and 100, that of absolute alcohol, both at 15° C. (59° F). The intermediate degrees, of course, show the percentage of absolute alcohol by volume at 15° C.; and the instrument is accompanied by the tables already given for ascertaining the percentage at any other temperature.

Alcoholometry of Liquids containing besides Alcohol, Saccharine Matters, Coloring Principles, &c., such as Wines, Beer, Liqueurs, &c.

In order to determine the proportion of absolute alcohol contained in wines or other mixtures of alcohol and water with saccharine and other non-volatile substances, the most accurate method consists in submitting a known volume of the liquid to distillation, (in a glass retort, for instance,) then, by determining the specific gravity of the distilled product, to ascertain the percentage of alcohol in this distillate, which may be regarded as essentially a mixture of pure alcohol and water. The distillation is carried out until the last portions have the gravity of distilled water; by then ascertaining the total volume of the distillate, and with the knowledge of its percentage of alcohol and the volume of the original liquor used, the method of calculating the quantity of alcohol present in the wine, or other liquor, is sufficiently obvious.

In carrying out these distillations, care must be taken to prevent the evaporation of the spirit from the distillate, by keeping the condenser cool. And Professor Mühler recommends the use of a refrigerator, consisting of a glass tube fixed in the centre of a jar, so that it may be kept filled with cold water. The tube must be bent at a right angle, and terminate in a cylindrical graduated measure-glass, shaped like a bottle. 

It is well to continue the distillation until about two-thirds of the liquid has passed over.

This process, though the most accurate for the estimation of the strength of alcoholic

* The Chemistry of Wine, by G. J. Mühler, edited by H. Beuce Jones, M. D.
liquors, is still liable to error. The volatile acids and ethers pass over with the alcohol into the distillate, and, to a slight extent, affect the specific gravity. This error may be, to a great extent, overcome by mixing a little chalk with the wine, or other liquor, previous to distillation.

By this method Professor Brande made, some years ago, determinations of the strength of the following wines, and other liquors *:

**Proportion of Spirit per Cent. by Measure.**

<table>
<thead>
<tr>
<th>Liquor</th>
<th>Average Spirit</th>
<th>Orange</th>
<th>Average Spirit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lissa</td>
<td>25-41</td>
<td>25-12</td>
<td>Average 11-26</td>
</tr>
<tr>
<td>Raisin</td>
<td>25-99</td>
<td>19-17</td>
<td></td>
</tr>
<tr>
<td>Marsala</td>
<td>22-56</td>
<td>22-27</td>
<td></td>
</tr>
<tr>
<td>Port (of 7 samples)</td>
<td>22-87</td>
<td>19-17</td>
<td></td>
</tr>
<tr>
<td>Madeira</td>
<td>19-79</td>
<td>19-79</td>
<td></td>
</tr>
<tr>
<td>Sherry (of 4 samples)</td>
<td>19-79</td>
<td>19-79</td>
<td></td>
</tr>
<tr>
<td>Teneriff</td>
<td>19-79</td>
<td>19-79</td>
<td></td>
</tr>
<tr>
<td>Lisbon</td>
<td>18-94</td>
<td>18-94</td>
<td></td>
</tr>
<tr>
<td>Malaga</td>
<td>18-94</td>
<td>18-94</td>
<td></td>
</tr>
<tr>
<td>Bacellas</td>
<td>18-49</td>
<td>18-49</td>
<td></td>
</tr>
<tr>
<td>Cape Madeira</td>
<td>20-51</td>
<td>20-51</td>
<td></td>
</tr>
<tr>
<td>Roussillon</td>
<td>19-00</td>
<td>19-00</td>
<td></td>
</tr>
<tr>
<td>Clayre</td>
<td>15-10</td>
<td>15-10</td>
<td></td>
</tr>
<tr>
<td>Sauterne</td>
<td>14-22</td>
<td>14-22</td>
<td></td>
</tr>
<tr>
<td>Burgundy</td>
<td>14-57</td>
<td>14-57</td>
<td></td>
</tr>
<tr>
<td>Hoek</td>
<td>12-98</td>
<td>12-98</td>
<td></td>
</tr>
<tr>
<td>Ten</td>
<td>12-90</td>
<td>12-90</td>
<td></td>
</tr>
<tr>
<td>Champagne</td>
<td>12-61</td>
<td>12-61</td>
<td></td>
</tr>
<tr>
<td>Gooseberry</td>
<td>11-84</td>
<td>11-84</td>
<td></td>
</tr>
</tbody>
</table>

The following results were obtained by the writer more recently by this process, (1854.)

**Percentage of Alcohol by Volume.**

<table>
<thead>
<tr>
<th>Liquor</th>
<th>Percentage of Alcohol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port (1834)</td>
<td>22.46</td>
</tr>
<tr>
<td>Sherry (Montilla)</td>
<td>19.95</td>
</tr>
<tr>
<td>Madeira</td>
<td>22.40</td>
</tr>
<tr>
<td>Champagne (Haut Brion)</td>
<td>10.9</td>
</tr>
<tr>
<td>Chamberlin</td>
<td>11.7</td>
</tr>
<tr>
<td>Sherry (low quality)</td>
<td>20.7</td>
</tr>
<tr>
<td>Sherry (brown)</td>
<td>23.1</td>
</tr>
<tr>
<td>Amontillado</td>
<td>20.5</td>
</tr>
<tr>
<td>Mansanilla</td>
<td>14.4</td>
</tr>
</tbody>
</table>

Port (best) 20.2
Marcobrunner 8.3
Champagne (1st) 12.12
Champagne (2d) 10.85
Home Ale 6.4
Export Ale 6.4
Strong Ale 9.0
Stout 5.7
Porter 4.18

M. l'Abbe Brossard-Vidal, of Toulon, has proposed to estimate the strength of alcoholic liquors by determining their boiling point. Since water boils at 100° C. (212° F.), and absolute alcohol at 78.4° (176° F.), it is evident that a mixture of water and alcohol will have a higher boiling point the larger the quantity of water present in it. This method is even applicable to mixtures containing other bodies in solution besides spirit and water, since it has been shown that sugar and salts, when present, (in moderate quantities,) have only a very trifling effect in raising the boiling point; and the process has the great advantage of facility and rapidity of execution, though, of course, not comparable to the method by distillation, for accuracy.

Mr. Field's patent (1847) alcoholometer is likewise founded upon the same principle. The instrument was subsequently improved by Dr. Ure.

The apparatus consists simply of a spirit-lamp placed under a little boiler containing the alcoholic liquor, into which fits a thermometer of very fine bore. When the liquor is stronger than proof-spirit, the variation in the boiling point is so small that an accurate result cannot possibly be obtained; and, in fact, spirit approaching this strength should be diluted with an equal volume of water before submitting it to ebullition, and then the result doubled. Another source of error is the elevation of the boiling point, when the liquor is kept heated for any length of time; it is, however, nearly obviated by the addition of common salt to the solution in the boiler of the apparatus, in the proportion of 3° or 40 grains. In order to correct the difference arising from higher or lower pressure of the atmosphere, the scale on which the thermometric and other divisions are marked is made movable up and

* Brande's Manual of Chemistry; also Philosophical Trans., 1811. † Comptes Rendus, xxvii. 574.
down the thermometer tube; and every time, before commencing a set of experiments, a preliminary experiment is made of boiling some pure distilled water in the apparatus, and the zero point on the scale (which indicates the boiling point of water) is adjusted at the level of the surface of the mercury.

But even when performed with the utmost care, this process is still liable to very considerable errors, for it is extremely difficult to observe the boiling point to within a degree; and after all, the fixed ingredients present undoubtedly do seriously raise the boiling point of the mixture—in fact, to the extent of from half to a whole degree, according to the amount present.

Silbermann's Method.—M. Silbermann* has proposed another method of estimating the strength of alcoholic liquors, based upon their expansion by heat. It is well known that, between zero and 100° C. (212° F.), the dilatation of alcohol is triple that of water, and this difference of expansion is even greater between 25° C. (77° F.) and 50° C. (122° F.); it is evident, therefore, that the expansion between these two temperatures becomes a measure of the amount of alcohol present in any mixture. The presence of salts and organic substances, such as sugar, coloring, and extractive matters, in solution or suspension in the liquid, is said not materially to affect the accuracy of the result; and M. Silbermann has devised an apparatus for applying this principle, in a ready and expeditious manner, to the estimation of the strength of alcoholic liquors. The instrument may be obtained of the philosophical instrument-makers of London and of Liverpool.

It consists of a brass plate, on which are fixed—1st, An ordinary mercurial thermometer graduated from 23° to 50° C. (77° to 122° F.), these being the working temperatures of the dilatometer; and 2dly, the dilatometer itself, which consists of a glass pipette, open at both ends, and of the shape shown in the figure. A valve of cork or india-rubber closes the tapering end, a, which valve is attached to a rod, b b, fastened to the supporting plate, and connected with a spring, n, by which the lower orifice of the pipette can be opened or closed at will. The pipette is filled, exactly up to the zero point, with the mixture to be examined—this being accomplished by the aid of a piston working tightly in the long and wide limb of the pipette; the action of which serves also another valuable purpose, viz., that of drawing any bubbles of air out of the liquid. By now observing the dilatation of the column of liquid when the temperature of the whole apparatus is raised, by immersion in a water-bath, from 23° to 50°, the coefficient of expansion of the liquid is obtained, and hence the proportion of alcohol—the instrument being, in fact, so graduated, by experiments previously made upon mixtures of known composition, as to give at once the percentage of alcohol.

Another alcoholometer, which, like the former, is more remarkable for the great facility and expedition with which approximate results can be obtained than for a high degree of accuracy, was invented by M. Geisler, of Bonn, and depends upon the measurement of the tension of the vapor of the liquid, as indicated by the height to which it raises a column of mercury.

Geisler's Alcoholometer.—It consists of a closed vessel in which the alcoholic mixture is raised to the boiling point, and the tension of the vapor observed by the depression of a column of mercury in one limb of a tube, the indication being rendered more manifest by the elevation of the other end of the column.

The wine or other liquor of which it is desired to ascertain the strength, is put into the little flask, s, which, when completely filled, is screwed on to the glass which contains mercury, and is closed by a stopcock at s. The entire apparatus, which at present is an inverted position, is now stood erect, the flask and lower extremity of the tube being immersed in a water-bath. The vigorous liquid is thus heated to a boiling point, and its vapor forces the mercury up into the long limb of the tube. The instrument having been graduated, once for all, by actual experiment, the percentage of alcohol is read off at once on the stem by the height to which the mercurial column rises.

To show how nearly the results obtained by this instrument agree with those obtained by the distillation process, comparative experiments were made on the same wines by Dr. Bence Jones.†

* Comptes Rendus, xxvii. 418.
### Table: Alcoholometry

<table>
<thead>
<tr>
<th>Spirit</th>
<th>By Distillation (Mr. Witt)</th>
<th>By Alcoholometer</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>per cent. by measure.</td>
<td>per cent. by measure.</td>
</tr>
<tr>
<td>Port, 1834</td>
<td>22.46</td>
<td>25.2</td>
</tr>
<tr>
<td>Sherry, Montilla</td>
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<td>20.6</td>
</tr>
<tr>
<td>Madeira</td>
<td>22.40</td>
<td>24.5</td>
</tr>
<tr>
<td>Haut Brion claret</td>
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<td>11.1</td>
</tr>
<tr>
<td>Chambertin</td>
<td>11.7</td>
<td>13.2</td>
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<tr>
<td>Low-quality sherry</td>
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<td>23.6</td>
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<tr>
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<td>23.3</td>
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<tr>
<td>Mansanilla</td>
<td>14.4</td>
<td>15.4</td>
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<tr>
<td>Port, best</td>
<td>20.2</td>
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</tr>
<tr>
<td>Marnobrunner</td>
<td>8.3</td>
<td>9.7</td>
</tr>
<tr>
<td>Home ale</td>
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<td>7.0</td>
</tr>
<tr>
<td>Export ale</td>
<td>6.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Strong ale</td>
<td>2.0</td>
<td>10.7</td>
</tr>
</tbody>
</table>

### Tabarie's Method

There is another method of determining the alcoholic contents of mixtures, which especially recommends itself on account of its simplicity. The specific gravity of the liquor is first determined, half its volume is next evaporated in the open air, sufficient water is then added to the remainder to restore its original volume, and the specific gravity again ascertained. By deducting the specific gravity before the expulsion of the alcohol from that obtained afterwards, the difference gives a specific gravity indicating the percentage of alcohol, which may be found by referring to Gay-Lussac’s or one of the other tables. Tabarie has constructed a peculiar instrument for determining these specific gravities, which he calls an oenometer; but they may be performed either by a specific-gravity bottle or by a hydrometer in the usual way.

Of course this method cannot be absolutely accurate; nevertheless, Prof. Mulder’s experience with it has led him to prefer it to any of the methods before described, especially where a large number of samples have to be examined. He states that the results are almost as accurate as those obtained by distillation. The evaporation of the solution may be accelerated by conducting hot steam through it.

### Adulterations

Absolute alcohol should be entirely free from water. This may be recognized by digesting the spirit with pure anhydrous sulphate of copper. If the spirit contain any water, the white salt becomes tinged blue, from the formation of the blue hydrated sulphate of copper.

Rectified spirit, proof spirit, and the other mixtures of pure alcohol and water, should be colorless, free from odor and taste. If containing methyl or amylic alcohols, they are immediately recognized by one or other of these simple tests.

Dr. Ure states, that if wood spirit be contained in alcohol, it may be detected to the greatest minuteness by the test of caustic potash, a little of which, in powder, causing wood spirit to become specifically yellow and brown, while it gives no tint to alcohol. Thus 1 per cent. of wood spirit may be discovered in any sample of spirits of wine.

The admixture with a larger proportion than the due amount of water is of course determined by estimating the percentage of absolute alcohol by one or other of the several methods just described in detail.

The adulterations and sophistications to which the various spirits known as rum, brandy whiskey, gin, &c., are subjected, will be best described under these respective heads, since these liquors are themselves mixtures of alcohol and water with sugar, coloring matters, flavoring others, &c.

### Alcoholde

By this word is understood the fluid obtained from alcohol by the removal of two equivalents of hydrogen. Thus, alcohol being represented by the formula $C\,H_2\,O_2$, aldehyde becomes $C\,H\,O$. 
Preparation.—Aldehyde is prepared by various processes of oxidation. Liebig has published several methods, of which the following is perhaps the best. Three parts of pyridine, three of sulphuric acid, two of water, and two of alcohol of 80 per cent., are well mixed and carefully distilled in a spacious retort. The extreme volatility of aldehyde renders good condensation absolutely necessary. The contents of the retort are to be distilled over a gentle and manageable fire until frothing commences, or the distillate becomes acid. This generally takes place when about one-third has passed over. The fluid in the receiver is to have about its own weight of chloride of calcium added, and, after slight digestion, is to be carefully distilled on the water-bath. The distillate is again to be treated in the same way. By these processes a fluid will be obtained entirely free from water, but containing several impurities. To obtain the aldehyde in a state of purity, it is necessary, in the first place, to obtain aldehyde-ammonia; this may be accomplished in the following manner:—The last distillate is to be mixed in a flask with twice its volume of ether, and, the flask being placed in a vessel surrounded by a freezing mixture, dry ammoniacal gas is passed in until the fluid is saturated. In a short time crystals of the compound sought separate in considerable quantity. The aldehyde-ammonia, being collected on a filter, or in the neck of a funnel, is to be washed with ether, and dried by pressure between folds of filtering paper, followed by exposure to the air. It now becomes necessary to obtain the pure aldehyde from the compound with ammonia. For this purpose two parts are to be dissolved in an equal quantity of water, and three parts of sulphuric acid, mixed with four parts of water, are to be added. The whole is to be distilled on the water-bath, the temperature, at first, being very low, and the operation being stopped as soon as the water boils. The distillate is to be placed in a retort connected with a good condensing apparatus, and, as soon as all the joints are known to be tight, chloride of calcium, in fragments, is to be added. The heat arising from the hydration of the chloride causes the distillation to commence, but it is carried on by a water-bath. The distillate, after one more rectification over chloride of calcium, at a temperature not exceeding 80° F., will consist of pure aldehyde. Aldehyde is a colorless, very volatile, and mobile fluid, having the density 0.806 at 32°. It boils, under ordinary atmospheric pressure, at 70° F. Its vapor density is 1.532. Its formula corresponds to four volumes of vapor; we consequently obtain the theoretical vapor density by multiplying its atomic weight = 44 by half the density of hydrogen, or 0.346. The number thus found is 1.5224, corresponding as nearly as could be desired to the experimental result.

Aldehyde is produced in a great number of processes, particularly during the destructive distillation of various organic matters, and in processes of oxidation. From alcohol, aldehyde may be procured by oxidation with platinum black, nitric acid, chromic acid, or a mixture of nitric acid and chromic acid (in presence of water), or, as we have seen, a mixture of peroxide of manganese and sulphuric acid. Certain oils, by destructive distillation, yield it. Wood vinegar in the crude state contains aldehyde as well as wood spirit. Lactic acid, when in a combination with weak bases, yields it on destructive distillation. Various animal and vegetable products afford aldehyde by distillation with oxidizing agents, such as sulphuric acid and peroxide of manganese, or bichromate of potash.

The word aldehyde, like that of alcohol, is gradually becoming used in a much more extended sense than it was formerly. By the term is now understood any organic substance which, by assimilating two equivalents of hydrogen, yields a substance having the properties of an alcohol or, by taking up two equivalents of oxygen, yields an acid. It is this latter property which has induced certain chemists to say that there is the same relation between an aldehyde and its acid as between inorganic acids ending in oxa and ic. Several very interesting and important substances are now known to belong to the class of aldehydes. The essential oils are, in several instances, composed principally of bodies having the properties of aldehydes. Among the most prominent may be mentioned the oils of bitter almonds, cinammon, ephedra, &c. An exceedingly important character of the aldehydes is their strong tendency to combine with the isulphites of ammonia, potash, and soda. By availing ourselves of this property, it becomes easy to separate bodies of this class from complex mixtures, and, consequently, enable a proximate analysis to be made. Now that the character of the aldehydes is becoming better understood, the chances of artificially producing the essential oils above alluded to in the commercial scale become greatly increased. Several have already been formed, and, although in very small quantities, the success has been sufficient to warrant sanguine hopes of success. A substitute for one of them has been for some years known under the very incorrect name of artificial oil of bitter almonds. See Nitrobenzole.—C. G. W.
ALEMBIC.

ALEMBIC, a still (which see). The term is, however, applied to a still of peculiar construction, in which the head, or capital, is a separate piece, fitted and ground to the neck of the boiler, or cunbril, or otherwise carefully united with a lute. The alembic has this advantage over the common retort, that the residue of distillation may be easily cleared out of the body. It is likewise capable, when skilfully managed, of distilling a much larger quantity of liquor in a given time than a retort of equal capacity. In France the term alembic, or rather alambic, is used to designate a glass still.

ALGAROTH, POWDER OF. Powder of Algarotti.—English Powder. This salt was discovered by Algarotti, a physician of Verona. Chloride of antimony is formed by boiling black sulphide of antimony with hydrochloric acid; on pouring the solution into water, a white fleshy precipitate falls, which is an oxichloride of antimony. If the water be hot, the precipitate is distinctly crystalline; this is the powder of algaroth. This oxichloride is used to furnish oxide of antimony in the preparation of tartar emetic.

ALGAE. (See red., Fr.; See, or Alerg, Germ.) A tribe of subaquous plants, including the seaweeds (fucus) and the lavers (ulva) growing in salt water, and the fresh water confervas. We have only to deal with those seaweeds which are of any commercial value. These belong to the great division of the jointless akor, of which 160 species are known as natives of the British Isles. In the manufacture of Kelp, (see KAR.) all the varieties of this division may be used. The edible sorts, such as the birds' nests of the Eastern Archipelago, those which we consume in this country, as lavers, carrageen, or Irish moss, &c., belong to the same group, as do also those which the agriculturalists employ for manure.

Dr. Pereira gives the following list of excellent seaweeds:—

Rhodomenia palustris (or Dulse) Rhodomenia Gigantea Laminaria saccharina

Rhodomenia palustris passes under a variety of names, dulse, dylish, or dillish, and amongst the Highlanders it is called drolling, or waterleaf. It is employed as food by the poor of many nations; when well washed, it is chewed by the peasantry of Ireland without being dressed. It is nutritious, but sudorific, has the smell of violets, imparts a mucilaginous feel to the mouth, leaving a slightly acid taste. In Ireland the dulse is thoroughly washed in fresh water and dried in the air. When thus treated it becomes covered with a white powdery substance, which is sweet and palatable; this is marnite, (see Manna,) which Dr. Stenhouse proposes to obtain from seaweeds. "In the dried state it is used in Ireland with fish and butter, or else, by the higher classes: boiled in milk with the addition of rye flour. It is preserved packed in close casks; a fermented liquor is produced in Kamchatka from this seaweed, and in the north of Europe and in the Greek Archipelago cattle are fed upon it."—Stenhouse.

Laminaria saccharina yields 12-15 per cent. of mannite, while the Rhodomenia palustris contains not more than 2 or 3 per cent.

Iridea edulis.—The fronds of this weed are of a dull purple color, flat, and succulent. It is employed as food by fishermen, either raw or pinched between hot irons, and its taste is then said to resemble roasted oysters.

Alaria esculenta.—Mr. Drummond informs us that, on the coast of Antrim, "it is often gathered for eating, but the part used is the leaflets, and not the midrib, as is commonly stated. These have a very pleasant taste and flavor, but soon cover the mouth with a tenacious greenish crust, which causes a sensation somewhat like that of the fat of a heart or kidney."—Stenhouse.

Ulua latissima. (Bread green laver.)—This is rarely used, being considered inferior to the Porphyra lacinita, (Laciniated purple laver.) This also is abundant on all our shores. It is pickled with salt, and sold in England as laver, in Ireland as aloke, and in Scotland as sloak. The London shops are mostly supplied with laver from the coasts of Devonshire. When stewed, it is brought to the table and eaten with pepper, butter or oil, and lemon-juice or vinegar. Some persons use it with leeks and onions. The pepper dulse, (Laminaria pinnatifida,) distinguished for its pungent taste, is often used as a condiment when other seaweeds are eaten. "Tangle," (Laminaria digitata,) so called in Scotland, is termed "red-ware" in the Orkneys, "sea-wand" in the Highlands, and "sea-girdles" in England. The flat leathery fronds of this weed, when young, are employed as food. Mr. Simmonds tells us, "There was a time when the cry of 'Buy dulse and tangle' was as common in the streets of Edinburgh and Glasgow, as is that of 'water-crackers' now in our metropolis."—Society of Arts Journal.

VARIETY 2.
Laminaria potatorum.—The large sea tangle is used abundantly by the inhabitants of the Straits of Magellan and by the Fuegians. Under the name of "Ball Kelp" it is used as food in New Zealand and Van Diemen's Land. It is stated to be exceedingly nutritious and fattening.

Chondrus crispus, (chordurs, from χουδρός, cartilage.)—Carrageen, Irish, or pearl moss, for purposes of diet and for medicinal uses, this alga is collected on the west coast of Ireland, washed, bleached by exposure to the sun, and dried. It is not unfrequently used in Ireland by painters and plasterers as a substitute for size. It has also been successfully applied, instead of isinglass, in making of blanc-mange and jellies; and in addition to its use in medicine, for which purpose it was introduced by Dr. Todhunter, of Dublin, about 1831, a thick mucilage of carrageen, scented with some prepared spirit, is sold as bandoline, freeze, or elyphilique, and is employed for stiffening silks. According to Dr. Davy, carrageen consists of

Gummy matter, .......................... 28-5
Gelatinous matter, ...................... 49-0
Insoluble matter, ....................... 22-5

100-0

Plocaria candida.—Ceylon moss; edible moss. This moss is exported from the islands of the Indian Archipelago, forming a portion of the cargoes of nearly all the junks. It is stated by Mr. Crawford, in his "History of the Indian Archipelago," that on the spots where it is collected, the prices seldom exceed from 5a. 8d. to 7a. 6d. per cwt. The Chinese use it in the form especially with sugar, as a sweetmeat, and apply it in the arts as an excellent paste. The gummy matter which they employ for covering lanterns, varnishing paper, &c, is made chiefly from this moss.

This moss, as ordinarily sold, appears to consist of several varieties of marine productions, with the Plocaria intermixed.

The Apam-Apam of Malacca belongs to this variety; and probably seaweeds of this character are used by the Salangans or esculent swallow in constructing their nests, which are esteemed so great a delicacy by the Chinese. The plant is found on the rocks of Palo Ticoos and on the shores of the neighboring islands. It is blanched in the sun for two days, or until it is quite white. It is obtained on submerged banks in the neighborhood of Macassar, Celebes, by the Bajow-laut, or sea-gipsies, who send it to China. It is also collected on the reefs and rocky submerged ledges in the neighborhood of Singapore. Mr. Montgomery Martin informs us that this weed is the chief staple of Singapore, and that it produces in China from six to eight dollars per pecul in its dry and bulky state. The harvest of this seaweed is from 6,000 to 12,000 peculs annually, the pecul being equal to 100 cattles of 1,333 lbs. each.

Similar to this, perhaps the same in character, is the Apam-Apam, a species of seaweed. It dissolves into a glutinous substance. Its principal use is for gumming silks and paper, as nothing equals it for paste, and it is not liable to be eaten by insects. The Chinese make a beautiful kind of lantern, formed of netted thread washed over with this gum, and which is extremely light and transparent. It is brought by coasting vessels to Prince of Wales Island, and calculated for the Chinese market.—Oriental Commercios.

ALIMENT. (Alimentum, from alis, to feed.) The food necessary for the human body, and capable of maintaining it in a state of health.

1. Nitrogenous substances are required to deposit, from the blood, the organized tissue and solid muscle;
2. And carbonaceous, non-nitrogenous bodies, to aid in the processes of respiration, and in the supply of carbonaceous elements, as fat, &c., for the due support of animal heat.

For information on these substances, consult Liebig's "Animal Chemistry," the investigations of Dr. Lyon Playfair, and Dr. Robert Dundas Thompson's "Experimental Researches on Food," 1846.

ALKALI. A term derived from the Arabians, and introduced into Europe when the Mahometan conquerors pushed their conquests westward. Al, cl, or al, as an Arabic noun, denotes "God, Heaven, Divine." As an Arabic particle, it is prefixed to words to give them a more emphatic signification, much the same as our particle the; as in Alcoran, the Koran; alekhynist, the chemist.

Kali was the old name for the plant producing potash, (the glasswort, so called from its use in the manufacture of glass,) and alkali signified no more than the kali plant. Potash and soda were for some time confounded together, and were hence called alkalis. Ammonia, which much resembles them when dissolved in water, was also called an alkali. Ammonia was subsequently distinguished as the volatile alkali, potash and soda being fixed alkalis. Ammonia was also called the animal alkali. Soda was the mineral alkali, being derived from rock salt, or from the ocean; and potash received the name of vegetable alkali, from its source being the ashes of plants growing upon the land. Alkalis are characterized by...
ALKALIS, ORGANIC.

being very soluble in water, by neutralizing the strongest acids, by turning brown vegetable yellows, and to green the vegetable reds and blues.

Some chemists classify all salifiable bases under this name.

In commercial language, the term is applied to an impure soda, the imports of which were—

**Imports.**

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<tr>
<th>Alkali and Barilla</th>
<th>1853</th>
<th>1854</th>
<th>1855</th>
<th>1856</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portugal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Cwts</td>
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<tr>
<td>Spain</td>
<td>-</td>
<td>-</td>
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<td>25,740</td>
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Our *Exports* during the same periods being as follows:

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<th>1855</th>
<th>1856</th>
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<tr>
<td>&quot; Southern Ports</td>
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<td>United States</td>
<td>-</td>
<td>550,735</td>
<td>559,942</td>
<td>494,254</td>
</tr>
<tr>
<td>Brazil</td>
<td>-</td>
<td>12,281</td>
<td>20,153</td>
<td>23,805</td>
</tr>
<tr>
<td>Chili</td>
<td>-</td>
<td>10,392</td>
<td>-</td>
<td>5,185</td>
</tr>
<tr>
<td>Other Countries</td>
<td>-</td>
<td>29,771</td>
<td>33,747</td>
<td>42,469</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>-</td>
<td>1,070,624</td>
<td>1,100,315</td>
<td>1,045,004</td>
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</table>

**ALKALIS, ORGANIC.** During the last few years the number of organic alkaloids has so greatly increased, that a considerable volume might be devoted to their history. There are, however, only a few which have become articles of commerce. The modes of preparation will be given under the heads of the alkaloids themselves. The principal sources from whence they are obtained are the following:— 1. The animal kingdom. 2. The vegetable kingdom. 3. Destructive distillation. 4. The action of potash on the cyanic and cyanamide ethers. 5. The action of ammonia on the iodides, &c., of the alcohol radicals. 6. The action of reducing agents on nitro-compounds. The principal bases existing in the animal kingdom are creatine and sarcosine. The vegetable kingdom is much richer in them, and yields a great number of organic alkaloids, of which several are of extreme value in medicine. Modern chemists regard all organic alkaloids as derived from the types ammonia or oxide of ammonium. Their study has led to results of the most startling character. It has been found that not only may the hydrogen in ammonia or oxide of ammonium be replaced by metals and compound radicals without destruction of the alkaline character, but even the nitrogen may be replaced by phosphorus or arsenic, and yet the resulting compounds remain powerfully basic. In studying the organic bases, chemists have constantly
had in view the artificial production of the bases of cinchona bark. It is true that this result has not as yet been attained; but, on the other hand, bodies have been formed having so many analogies, both in constitution and properties, with the substances sought, that it cannot be doubted the question is merely one of time. The part performed by the bases existing in the juice of flesh has not been ascertained, and no special remedial virtues have been detected in them; but this is not the case with those found in vegetables; it is, in fact, among them that the most potent of all medicines are found—such, for example, as quinine and morphia. It is, moreover, among vegetable alkaloids that we find the substances most inimical to life, for acotoine, atropine, brucine, couline, curarine, nicotine, solanine, strychnine, &c, &c, are among their number. It must not be forgotten, however, that, used with proper precaution, even the most virulent are valuable medicines. The fearfully poisonous nature of some of the organic bases, together with an idea that they are difficult to detect, has unhappily led to their use by the poisoner; strychnine, especially, has acquired a painful notoriety, in consequence of its employment by a medical man to destroy persons whose lives he had insured. Fortunately for society, the skill of the analyst has more than kept pace with that of the poisoner; and without regarding the extravagant assertions made by some chemists as to the minute quantities of vegetable poisons they are able to detect, it may safely be asserted that it would be very difficult to administer a fatal dose of any ordinary vegetable poison without its being discovered. Another check upon the poisoner is found in the fact that these most difficult of isolation from complex mixtures are those which cause such distinct symptoms of poisoning in the victim, that the medical attendant, if moderately observant, can scarcely fail to have his suspicions aroused.

Under the heads of the various alkaloids will be found (where deemed of sufficient importance) not merely the mode of preparation, but also the easiest method of detection.

—C. G. W.

ALKALIMETER. There are various kinds of alkalimeters, but it will be more convenient to explain their construction and use in the article on Alkalimetry, to which the reader is referred.

ALKALIMETRY. 1. The object of alkalimetry is to determine the quantity of caustic alkali or of carbonate of alkali contained in the potash or soda of commerce. The principle of the method is, as in acidimetry, based upon Dalton's law of chemical combining ratios—that is, on the fact that in order to produce a complete reaction, a certain definite weight of reagent is required, or, in other words, in order to saturate or completely neutralize, for example, one equivalent of a base, exactly one equivalent of acid must be employed, and vice versa. This having been thoroughly explained in the article on Acidimetry, the reader is referred thereto.

2. The composition of the potash and of the soda met with in commerce presents very great variations; and the value of these substances being, of course, in proportion to the quantity of real alkali which they contain, an easy and rapid method of determining that quantity is obviously of the greatest importance both to the manufacturer and to the buyer. The process by which this object is attained, though originally contrived exclusively for the determination of the intrinsic value of these two alkalis, (whence its name, Alkalimetry,) has since been extended to that of ammonia and of earthy bases and their carbonates, as will be shown presently.

3. Before, however, entering into a description of the process itself, we will give that of the instrument employed in this method of analysis, which instrument is called an alkalimeter.

4. The common alkalimeter is a tube closed at one end, (see figure in margin,) of about ⅓ of an inch internal diameter, about 9½ inches long, and thus capable of containing 1,000 grains of pure distilled water. The space occupied by the water is divided accurately into 100 divisions, numbering from above downwards, each of which, therefore, represents 10 grains of distilled water.

5. When this alkalimeter is used, the operator must carefully pour the acid from it by closing the tube with his thumb, so as to allow the acid to trickle in drops as occasion may require; and it is well also to smear the edge of the tube with tallow, in order to prevent any portion of the test acid from being wasted by running over the outside after pouring which accident would, of course, render the analysis altogether inaccurate and worthless; and, for the same reason, after having once begun to pour the acid from the alkalimeter by allowing it to trickle between the thumb and the edge of the tube, as above mentioned, the thumb must not be removed from the tube till the end of the experiment, for otherwise the portion of acid which adheres to it would, of course, be wasted and vitiate the result. This uncomfortable precaution is obviated in the other forms of alkalimeter now to be described.
ALKALIMETRY.

6. That represented in fig. 12 is Gay-Lussac’s alkalimeter; it is a glass tube about 14 inches high, and \( \frac{1}{4} \) an inch in diameter, capable of holding more than 1,000 grains of distilled water; it is accurately graduated from the top downwards into 100 divisions, in such a way that each division may contain exactly 10 grains of water. It has a small tube, \( b \), communicating with a larger one, which small tube is bent and bevelled at the top, \( c \). This very ingenious instrument, known also under the name of “burette” and “pomut,” was contrived by Gay-Lussac, and is by far more convenient than the common alkalimeter, as by it the test acid can be unerringly poured, drop by drop, as wanted. The only drawback is the fragility of the small side-tube, \( b \), on which account the common alkalimeter, represented in fig. 11 is now generally used, especially by workmen, because, as it has no side-tube, it is less liable to be broken; but it gives less accurate results, a portion of the acid being wasted in various ways, and it is, besides, less manageable. Gay-Lussac’s “burette” is therefore preferable; and if melted wax be run between the space of the large and of the small tube, the instrument is rendered much less liable to injury; it is generally sold with a separate wooden foot or socket, in which it may stand vertically.

7. The following form of alkalimeter, (fig. 13,) which I contrived several years ago, will, I think, be found equally delicate but more convenient still than that of Gay-Lussac. It consists of a glass tube, \( \lambda \), of the same dimensions, and graduated in the same manner as that of Gay-Lussac; but it is provided with a glass foot, and the upper part, \( n \), is shaped like the neck of an ordinary glass bottle; \( c \) is a bulb blown from a glass tube, one end of which is ground to fit the neck, \( n \), of the alkalimeter, like an ordinary glass stopper. This bulb is drawn to a capillary point at \( n \), and has a somewhat large opening at \( x \). With this instrument the acid is perfectly under the control of the operator, for the globular joint at the top enables him to see the liquor before it actually begins to drop out, and he can then regulate the pouring to the greatest nicety, whilst its great delicacy, whilst its more substantial form renders it much less liable to accidents than that of Gay-Lussac; the glass foot is extremely convenient, and is at the same time a great additional security. The manner of using it will be described further on.

8. Another alkalimeter of the same form as that which I have just described, except that it is all in one piece, and has no globular enlargement, is represented in fig. 14. Its construction is otherwise the same, and the results obtained are equally delicate; but it is less under perfect control, and the test acid is very liable to run down the tube outside; this defect might be easily remedied by drawing the tube into a finer and more delicate point, instead of in a thick, blunted projection, from which the last drop cannot be detached, or only with difficulty, and imperfectly. A glass foot would, moreover, be an improvement.

9. With Schüster’s alkalimeter, (represented in fig. 15,) the strength of alkalis is determined by the weight, not by the measure, of the acid employed to neutralize the alkali; it is, as may be seen, a small bottle of thin glass, having the form of the head of the alkalimeter represented in fig. 13. We shall describe further on the process of analysis with this alkalimeter.

10. There are several other forms of alkalimeter, but those which have been alluded to are almost exclusively used, and whichever of them is employed, the process is the same—namely, pouring carefully an acid of a known strength into a known weight of the alkali under examination, until the neutralizing point is obtained, as will be fully explained presently.

11. Blue litmus-paper being immediately reddened by acids is the reagent used for ascertaining the exact point of the neutralization of the alkali to be tested. It is prepared by pulverizing one part of commercial litmus, and digesting it in six parts of cold water, filtering, and dividing the blue liquid into two equal portions, adding carefully to one of the portions, and one drop at a time, as much very dilute sulphuric acid as is sufficient to impart to it a slight red color, and pouring the portion so treated into the second portion, which is intensely blue, and stirring the
whole together. The mixture so obtained is neutral, and by immersing slips of white blotting-paper into it, and carefully drying them by hanging them on a stretched piece of thread, an exceedingly sensitive test paper of a light blue color is obtained, which should be kept in a wide-mouth glass-stoppered bottle, and sheltered from the air and light.

12. Since the principle on which alkalimetry is based consists in determining the amount of acid which a known weight of alkali can saturate or neutralize, it is clear that any acid having this power can be employed.

13. The test acid, however, generally preferred for the purpose is sulphuric acid, because the normal solution of that acid is more easily prepared, is less liable to change its strength by keeping, and has a stronger reaction on litmus-paper than any other acid. It is true that other acids—tartaric, for example—can be procured of greater purity, and that, as it is dry and not caustic, the quantities required can be more comfortably and accurately weighed off; and on this account some chemists, after Buchner, recommended its use, but the facility with which its aqueous solution becomes moidly is so serious a drawback, that it is hardly ever resorted to for that object.

14. When sulphuric acid is employed, the pure acid in the maximum state of concentration, or, as it is called by chemists, the pure hydrate of sulphuric acid, specific gravity 1.8485, is preferable. Such an acid, however, is never met with in commerce, for the ordinary English oil of vitriol is seldom pure, and never to the maximum state of concentration; the operator, however, may prepare it by distilling ordinary oil of vitriol, but as the specific caloric of the vapor of sulphuric acid is very small, the distillation is a what hazardous operation, unless peculiar precaution be taken. The following apparatus, however, allows of the acid being distilled in a perfectly safe and convenient manner; it consists of a glass retort, charged with oil of vitriol, a little protosulphate of iron is added, for the purpose of destroying any nitrous products which the acid may evolve, and it is then placed into a cylinder of iron, the bottom of which is perforated with holes about three-quarters of an inch in diameter, except in the middle, where a large hole is cut of a suitable size for the retort to rest upon; the sides of the cylinder are likewise perforated, as represented in fig. 16. Ignited charcoal is then placed all round the retort, the bottom of which protruding, out of the influence of the heat, allows the ebullition to proceed from the sides only. It is well to put into the retort a few fragments of quartz or a few lengths of platinum wire, the effect of which is to render the ebullition more regular.

15. In order to prevent the acid fumes from condensing in the neck of the retort, it should be covered with a cover of sheet iron, as represented in fig. 16.

16. The first fourth part which distills over should be rejected, because it is too weak; the next two-fourths are kept, and the operation is then stopped, leaving the last fourth part of the acid in the retort. The neck of the retort should be about four feet long; and about one and a half inches in the bore, and be connected with a large receiver; and as the necks of retorts are generally much too short for the purpose, an adapter tube should be adjusted to it and to the receiver, but very loosely; this precaution is absolutely necessary, for otherwise the hot acid falling on the sides of the receiver would crack it; things, in fact, should be so arranged that the hot drops of the distilling acid may fall into the acid which has already distilled over. Do not surround the receiver with cold water, for the hot acid dropping on the refrigerated surface would also certainly crack it. The acid so obtained is pure oil of vitriol, or monohydrated sulphuric acid, SO\text{I}, HO, and it should be kept in a well-stoppered and dry flask.

17. For commercial assays, however, and, indeed, for every purpose, the ordinary concentrated sulphuric acid answers very well: when used for the determination of the value of potashes, it is made of such a strength that each division (or 10 water-grains' measure) of the alkalimeter saturates exactly one grain of pure potash: an acid of that particular strength is prepared as follows:—

18. Take 112:76 grains of pure neutral and anhydrous carbonate of soda, and dissolve them in about 5 fluid ounces of hot water.* This quantity, namely, 112:76 grains, of neutral carbonate of soda will exactly saturate the same quantity of pure sulphuric acid (SO\text{I}) that 100 grains of pure potash would. It is advisable, however, to prepare at once a larger quantity of test solution of carbonate of soda, which is of course easily done, as will be shown presently.

* Anhydrous, or dry, neutral carbonate of soda may be obtained by keeping a certain quantity of pure bicarbonate of soda for a short time, at a dull red heat, in a platinum crucible: the bicarbonate is everted into its neutral carbonate, of course free from water.
19. Mix, now, 1 part, by measure, of concentrated sulphuric acid with 10 parts of water, or rather—as it is advisable, where alkalimetrical assays have frequently to be made, to keep a stock of test acid—mix 1,000 water-grains' measure of concentrated sulphuric acid with 10,000 grains of water, or any other larger proportions of concentrated sulphuric acid and water, in the above respective proportions; stir the whole well, and allow it to cool. The mixture of the acid with the water should be made by first putting a certain quantity of the water into a glass beaker or matras of a suitable size, then pouring the concentrated acid slowly therein, while a gyratory motion is imparted to the liquid. The vessel containing the acid is then rinsed with the water, and both the rinsing and the rest of the water are then added to the whole mass. When quite cold, fill the graduated alkalimeter with a portion of it up to the point marked 0°, taking the under line of the liquid as the true level; and, whilst stirring briskly with a glass rod the aqueous solution of the 112.75 grains of neutral carbonate of soda above alluded to, drop the test acid from the alkalimeter into the vortex produced by stirring, until, by testing the alkaline solution with a strip of reddened litmus-paper after every addition of acid, it is found that it no longer shows an alkaline reaction, (which is known by the slip of reddened litmus-paper not being rendered blue,) but, on the contrary, indicates that a very slight excess of acid is present, (which is known by testing with a slip of blue litmus-paper, which will then turn slightly red.)

20. If, after having exhausted the whole of the 100 divisions (1,000 water-grains' measure) of the diluted acid in the alkalimeter, the neutralization is found to be exactly attained, it is a proof that the test acid is right.

21. But suppose, on the contrary, (and this is a much more probable case,) suppose that only 80 divisions of the acid in the alkalimeter have been required to neutralize the alkaline solution, it is then a proof that the test acid is too strong, and accordingly it must be further diluted with water, to bring it to the standard strength; and this may at once be done, in the present instance, by adding 20 measures of water to every 80 measures of the acid. This is best accomplished by pouring the whole of the acid into a large glass cylinder, divided into 100 equal parts, until it reaches the mark or scratch corresponding to 80 measures; the rest of the glass, up to 100, is then filled up with water, so that the same quantity of real acid will now be in the 100 measures as was contained before in 80 measures.

22. The acid adjusted as just mentioned should be labelled "Test Sulphuric Acid for Potash," and kept in well-stoppered bottles, otherwise evaporation taking place would render the remaining bulk more concentrated, consequently richer in acid than it should be, and it would thus, of course, become valueless as a test acid until readjusted. Each degree or division of the alkalimeter of such an acid represents 1 grain of pure potash.

23. The alkaliometric assay of soda is also made with sulphuric acid, in preference to other acids, but it must be so adjusted that 100 alkaliometrical divisions (1,000 water-grains' measure) of acid will exactly neutralize 170°-98 of pure anhydrous carbonate of soda, that quantity containing 100 grains of pure soda.

24. Dissolve, therefore, 171 grains of pure anhydrous neutral carbonate of soda, obtained as indicated before, in five or six ounces of hot water, and prepare in the meantime the test sulphuric acid, by mixing 1 part, by measure, of ordinary concentrated sulphuric acid, with about 9 parts, by measure, of water, exactly as described before; stir the whole thoroughly, let the mixture stand until it has become quite cold, then pour 1,000 water-grains' measure of the dilute acid so prepared into an alkalimeter—that is to say, fill that instrument up to 0°, taking the under line as the true level, and then, whilst stirring briskly the aqueous solution of the 171 grains of carbonate of soda with a glass rod, pour the acid, with increased precaution as the saturating point is approaching, into the vortex produced, until by testing the liquor alternately with reddened and with blue litmus-paper, or with gray litmus-paper, as before mentioned, the exactly neutralized point is hit.

25. If the whole of the 100 alkaliometrical divisions (1,000 water-grains' measure) have been required to effect the neutralization, it is a proof that the acid is of the right strength; but if this be not the case, it must be adjusted as described before—that is to say—

26. Suppose, for example, that only 75 alkaliometrical divisions or measures of the acid in the alkalimeter have been required to neutralize the 171 grains of neutral carbonate of soda operated upon, then 75 measures of the acid should be poured at once into a glass cylinder accurately divided into 100 parts; the remaining 25 divisions should then be filled with water, and the whole being now stirred up, 100 parts of the liquor will of course contain as much real acid as 75 parts contained before, and accordingly the acid may now be used as a test acid for the alkaliometrical assay of soda, each degree or division of the alkalimeter representing one grain of pure soda.

27. The stock of test acid should be kept in well-stoppered flasks, that it may not vary in strength by evaporation, and be labelled "Test Sulphuric Acid for Soda."

28. Instead, however, of keeping two kinds of "test sulphuric acid," of different saturating powers as described, the one for potash, the other for soda, one kind only may be
prepared so as to serve for both alkalis, by constructing, as is very often done, an alkalimeter adjusted so as to indicate the quantities of the acid of a given strength required for the saturation of neutralization of both potash or soda, or of their respective carbonates; and this, in fact, is the alkalimeter most in use in the factory.

It should be in shape similar to that of Gay-Lussac's, (see fig. 12,) or that described in figs. 13 and 14; but, like that represented by fig. 11, it generally consists of a tube closed at one end, about three-fourths of an inch internal diameter and about 9 inches in length; it is graduated into 100 equal parts, and every division is numbered from above downwards (see fig. 17).

The following directions for their construction are given by Professor Faraday: "Let the tube represented in the margin have 100" grains of water weighed into it; then let the space it occupies be graduated into 100 equal parts, and every ten divisions numbered from above downwards. At 224 parts, or 77-99 parts from the bottom, make an extra line, a little on one side or even on the opposite side of the graduation, and write at it with a scratching diamond, 'soda'; lower down, at 48-62 parts, make another line, and write 'potash'; still lower, at 54-43 parts, a third line marked 'carb. soda'; and at 65 part, a fourth, marked 'carb. potash.' It will be observed that portions are measured off beneath these marks in the inverse order of the equivalent number of these substances, and consequently directly proportionate to the quantities of any particular acid which will neutralize equal weights of the alkalis and their carbonates. As these points are of great importance, it will be proper to verify them by weighing into the tubes first 350, then 518-8, and lastly 779-9 grains of water, which will correspond with the marks if they are correct, or the graduation may be laid down from the surface of the four portions of fluid when weighed in, without reference to where they fall upon the general scale. The tube is now completed, except that it should be observed whether the aperture can be perfectly and securely covered by the thumb of the left hand, and if not; or, if there be reason to think it not ultimately secure, then it should be heated and contracted until sufficiently small."

29. The test acid for this alkalimeter should have a specific gravity of 1.1268; and such an acid may be prepared by mixing one part, by weight, of sulphuric acid, specific gravity 1:82, with four parts of water, and allowing the mixture to cool. In the meantime, 100 grains of pure anhydrous carbonate of soda, obtained as indicated before, should be dissolved in water, and the test sulphuric acid, of specific gravity 1:1268, prepared as above said, having become quite cool, is poured into the alkalimeter up to the point marked carbonate of soda, the remaining divisions are filled up with water, and the whole should be well mixed by shaking.

30. If the whole of the sulphuric acid, adjusted as was said, being poured carefully into the solution of the 100 grains of the neutral carbonate of soda, neutralize them exactly—which is ascertained, as usual, by testing the solution with limna-paper, which should not be either reddened or rendered bluer by it—it is of course a sign that the test as is should be—that is to say, is of the proper strength; in the contrary case, it must be finally adjusted in the manner already indicated, and which need not be repeated. See §§ 29, 21.

31. The best and most convenient process for the analyst, however, consists in preparing a test acid of such a strength that it may serve not only for all alkalis, but indeed for every base; that is to say, by adjusting the test acid so that 100 alkalimetrical divisions of it (1,000 water-grains' measure) may exactly saturate or neutralize one equivalent of every base. This method, which was first proposed by Dr. Ure, is exceedingly convenient, and the possession of two reciprocal test liquids, namely the ammoniacal test liquid of a standard strength, of which we gave a description in the article on Acidimetry, and the standard test acid of which we are now speaking, affords, as Dr. Ure observes, ready and rigid means of verification. For microscopic analysis of alkaline and of acid matter, a graduated tube of a small bore, mounted in a frame, with a valve apparatus at top, so as to let drop from any size and at any interval, is desirable; and such an instrument Dr. Ure employed for many years; but instead of a tube with a valve apparatus at top, the operator may use a graduated tube of a small bore, terminated by a small length of vulcanized india-rubber tube pinched in a clamp, which may be relaxed in such a way as to permit also the escape of drops of any size at any interval of time, the little apparatus being under perfect command.

32. The test sulphuric acid, of such a strength that 100 alkalimetrical divisions of it can saturate one equivalent of every base, should have a specific gravity of 1:082, and is prepared as follows:—

Take 53 grains (one equivalent) of pure anhydrous neutral carbonate of soda, obtained
in the manner indicated before, (see § 18,) and dissolve them in about one fluid ounce of water. Prepare, in the meantime, the test sulphuric acid by mixing one part, by measure, of concentrated sulphuric acid with about 11 or 12 parts of water, and stir the whole well. The mixture having become quite cold, fill the alkalimeter with the cold diluted acid up to the point marked 0', taking the under line of the liquid as the true level, and, whilst stirring briskly the aqueous solution of the 53 grains of carbonate of soda above alluded to, pour the acid carefully from the alkalimeter into the vortex produced by stirring, until, by testing the liquor alternately with red litmus and with blue litmus-paper, or, more conveniently still, with gray litmus-paper, the neutralizing point is exactly hit.

33. If the whole of the 100 divisions of the alkalimeter had been required to neutralize exactly the 53 grains of pure anhydrous carbonate of soda, it would be a proof that the acid is of the right strength; but if this is not the case, it must be adjusted in the manner described before, that is to say—

34. Let us suppose, for example, that only 50 measures in the alkalimeter have been required to saturate or neutralize the 53 grains of carbonate of soda, then 50 measures should be poured at once into a glass cylinder accurately divided into 100 parts, the remaining 50 divisions should be filled up with water, and the whole being well stirred, 100 parts of the acid liquor will now contain as much real acid as was contained before in the 50 parts.

35. The acid may now be labelled simply, "Test or Normal Sulphuric Acid." Each one hundred alkalimetric divisions, or 1,000 water-grains' measure of it, contain one equivalent, or 40 grains of real sulphuric acid; and, consequently, each 100 alkalimetric divisions of it will neutralize one equivalent, or 51 grains of soda, 47 of potash, 17 of ammonia, 23 of lime, and so forth, with respect to any other base.

36. The stock of test or normal sulphuric acid should, as usual, be kept in well-stoppered bottles, in order to prevent concentration by evaporation. By keeping in the flask containing it a glass bead, exactly adjusted to the specific gravity of 1-032, the operator may always ascertain, at a glance, whether the acid requires readjusting.

37. With a Schützer's alkalimeter, it is convenient to prepare the test acid of such a strength that, according as it has been adjusted for potash or for soda, 10 grains of it will exactly saturate one grain of one or the other of these bases in a pure state. It is considered that the alkalimeter may be charged with a known weight of any of the other sulphuric test acids of a known strength. Suppose, for example, that the test sulphuric acid taken have a specific gravity of 1-032, we know, as we have just shown, that 1-032 grains' weight of that acid contains exactly one equivalent of pure sulphuric acid = 40, and is capable, therefore, of neutralizing one equivalent of any base; and, consequently, by taking a certain weight of this acid before beginning the assay, and weighing what is left of it after the assay, it is very easy to calculate, from the quantity of acid consumed in the experiment, what quantity of base has been neutralized. Thus a loss of 21-96 — 60-70 — 38-79 grains' weight of this test acid represents one grain of potash of ammonia, of soda respectively, and so on with the other bases.

38. The operator being thus provided with an appropriate test acid, we shall now describe how he should proceed with each of them in making an alkalimetric assay with potash.

In order to obtain a reliable result, a fair average sample must be operated upon. To secure this the sample should be taken from various parts of the mass, and at once put in a wide-mouth bottle, and well corked up until wanted; when the assay has to be made, the contents of the bottle must be reduced to powder, so as to obtain a fair mixture of the whole; of this weigh out 1,000 grains exactly—or less, if that quantity cannot be spared—and dissolve them in a porcelain capsule in about 8 fluid ounces of distilled hot water, or in that proportion; and if there be left any thing like an insoluble residue, filter, in order to separate it, and wash it on the filter with small quantities of distilled water, and pour the whole solution, with the washings and rinsings, into a measure divided into 10,000 water-grains' measure. If the water used for washing the insoluble residue on the filter has increased the bulk of the solution beyond 10,000 water-grains' measure, it must be reduced by evaporation to that quantity; if, on the contrary, the solution poured in the measure stands below the mark 10,000 water-grains' measure, then as much water must be added thereto as will bring the whole mass exactly to that point. In order to do this correctly, the cylindrical measure should stand well on a table, and the under or lower line formed by the liquid, as it reaches the scratch 10,000, is taken as the true level.

39. This being done, 1,000 grains' measure of the filtrate, that is to say, one-tenth part of the whole solution, is transferred to a glass beaker, in which the saturation or neutralization is to be effected, which is best done by means of a pipette capable of containing
exactly that quantity when filled up to the scratch, a. In order to fill such a pipette it is sufficient to dip it into the alkaline solution and to suck up the liquor a little above the scratch, a; the upper orifice should then be stopped with the first finger, and by momentarily lifting it up, the liquor is allowed slowly to fall from the pipette back again into the 10,000 grains' measure until its level reaches exactly the scratch, a. The last drop which remains hanging from the point of the pipette may be readily detached by touching the sides of the glass measure with it. The 1,000 grains being thus rigorously measured in the pipette should then be transferred to the glass beaker, in which the neutralization is to take place, by removing the finger altogether, blowing into it to detach the last drop, and rinsing it with a little water.

Moreover, instead of the pipette just described, the operator may measure 1,000 grains by taking an alkalimeter full of the alkaline solution, and emptying it into the glass beaker in which the neutralization is to take place, rinsing it with a little water, and of course adding the rinsing to the mass in the said glass beaker.

41. Whichever way is adopted, a slight blue color should be imparted to the 1,000 grains' measure of the alkaline solution, by pouring into it a small quantity of tincture of litmus. The glass beaker should then be placed upon a sheet of white paper, or a slab of white porcelain, in order that the change of color produced by the gradual addition of the test acid may be better observed.

42. This being done, if the operator has decided upon using the test sulphuric, for potash (§§ 17-22), he should take one of the alkalimeters, represented in figs. 11, 12, 13, or 14, and fill it up to 0\(^{°}\), (taking the under line of the liquid as the true level,) then taking the point of neutralization in his right hand, and in his left the glass beaker containing the alkaline solution colored blue by tincture of litmus, he should gradually and carefully pour the acid liquor into the alkaline solution in the glass beaker, to which a circular motion should be given whilst pouring the acid, or which should be briskly stirred, in order to insure the rapid and thorough mixing of the two liquids, and therefore their complete reaction; moreover, if at times to detect any change of color from blue to red, the glass beaker should be kept over the white sheet of paper or the white porcelain slab, as before stated.

43. At first no effervescence is produced, because the carbonic acid expelled, instead of escaping, combines with the portion of the alkaline carbonate as yet undecomposed, which it converts into bicarbonate of potash, and accordingly no sensible change of color is perceived; but as soon as a little more than half the quantity of the potash present is saturated, the liquor begins to effervescce, and the blue color of the solution is changed into one of a vinous, that is, of a purple or bluish-red hue, which is the solution of the acid carbonic upon the blue color of the litmus. More acid should be still added, but from this moment with very great care and with increased caution, gradually as the point of neutralization is approached, which is ascertained by drawing the glass rod used for stirring the liquor across a slip of blue litmus-paper. If the paper remains blue, or if a red or reddish streak is thereby produced which disappears on drying the paper and leaves the latter blue, it is a proof that the neutralization is not yet complete, and that the reddish streak was due only to the action of the carbonic acid; more acid must accordingly be poured from the alkalimeter, but one drop only at a time, stirring after each addition, until at last the liquid assumes a distinct red or pink color, which happens as soon as it contains an extremely slight excess of acid; the streaks made now upon the litmus-paper will remain permanently red, even after drying, and this indicates that the reaction is complete, and that the assay is finished.

44. If the potash under examination were perfectly caustic, the solution would suddenly change from blue to pink, because there would be no evolution of carbonic acid at all, and consequently no vinous or purple color produced; if, on the other hand, the potash was altogether in the state of bicarbonate, the first drops of test acid would at once decompose part of it and liberate carbonic acid, and impart a vinous color to the solution at the very outset, which vinous color would persist as long as any portion of the bicarbonate would remain undecomposed.

45. The neutralizing point being attained, the operator allows the sides of the alkalimeter to drain, and he then reads off the number of divisions which have been employed. If, for example, 50 divisions have been used, then the potash examined contained 50 per cent. of real potash. See observ., §§ 18-40.

46. Yet it is advisable to repeat the assay a second time, and to look upon this first determination only as an approximation which enables the operator, now that he knows about where the point of neutralization lies, to arrive, if need be, by increased caution as he reaches that point, at a much greater degree of precision. He should accordingly take again an alkalimeter full (1,000 water-grains' measure)—that is to say, another tenth part of the liquor left in the 10,000 grains' measure—and add thereto at once 48 or 49 alkalimetical divisions of the test acid, and after having thorougly agitated the mixture, proceed to pour the acid carefully, two drops only at a time, stirring after such addition, and
touching a strip of litmus-paper with the end of the glass rod used for stirring; and so he should go on adding two drops, stirring, and making a streak on the litmus-paper, until the liquid assumes suddenly a pink or onion-red color, and the streak made on the litmus-paper is red also. The alkalimeter is then allowed to drain as before, and the operator reads off the number of divisions employed, from which number two drops (or 1/2 of a division) should be deducted; Gay-Lussac having shown that, in alkalimetical assays, the sulphates of alkalis produced retard the manifestation of the red color in that proportion. One alkalimetical division generally consists of 10 drops, but as this is not always the case, the operator should determine for himself how many drops are necessary to make up one division, and take account of them in the assay according to the ratio thus found. In the example given before, and supposing 10 drops to form one alkalimetical division, then the percentage value of the sample of potash under examination would probably be as follows:—

| Number of divisions of acid employed, | . | . | 50:0 |
|—2 drops acid in excess, | . | . | 0:2 |
| Real percentage of potash, | . | . | 49:8 |

47. When the alkalimeter described in fig. 13 is employed, the test acid may, at the beginning of the experiment, be poured from the larger opening, \( V \); but towards the end—that is, when the neutralizing point is approaching—the acid should be carefully poured from the point, \( P \), in single drops, or only two drops at a time, until the saturating point is hit, as we have just said. If the operator wishes to pour only one drop, he should close the larger opening, \( V \), of the bulb with the thumb, and then fill the bulb with the test acid by inclining the alkalimeter; putting now the alkalimeter in an upright position, and removing the thumb, a certain quantity of acid will be retained in the capillary point, \( V \); and if the thumb be now pressed somewhat forcibly against the opening, \( V \), the acid contained in the capillary point will be forced out and form one drop, which will then fall into the alkaline solution if it be held over it. If the saturation be complete, the operator, without removing the bulb stopper, may, by applying his lips to the large opening, \( V \), suck the acid engaged in the capillary point back into the alkalimeter.

48. If there should be in the mind of the operator any doubt as to what is meant by the onion-red color which the liquid tinged blue with tincture of litmus acquires when slightly superposed on pure water, he may pour into a glass beaker a quantity of pure water equal to the volume larger than, the alkaline solution operated upon, and tinge it blue with a little tincture of litmus, to about the same degree of intensity as the alkaline liquid under examination. If he now pour into the pure water colored blue with litmus, one single drop of the test acid, it will acquire at once, by stirring, the onion-red color alluded to, and which he may now use as a standard of comparison.

49. Considering the rapidity with which these alkalimetical operations can be performed, the operator, unless he has acquired sufficient practice, or unless a great degree of accuracy be not required, should repeat the assay two or three times, looking upon the first determination only as an approximation, and as a sort of guide as to the quantity of acid which will be required in the subsequent experiments, whereby he will now be enabled to proceed with increased caution as he approaches the point of saturation; but, at any rate, if he will not take the little extra trouble of a repetition, he should, before he begins to pour the acid, take a little of the filtered alkaline solution out of the glass beaker, as a corps de réserve, which he adds to the rest after the saturating point has been approximated, and from that moment he may proceed, but with great care, to complete the neutralization of the whole.

50. Do not forget that, as the test sulphuric acid must always be added in slight excess to obtain a distinct red streak on the litmus-paper, a correction is absolutely necessary; that is to say, the excess of sulphuric acid employed must be deducted if a strictly accurate result is sought.

51. If, instead of the special alkalimeter for potash above described, the operator prefers using that prepared of such a strength that 100 divisions of the alkalimeter (100 water-grains measure) contain exactly one equivalent of each alkali or base, which test sulphuric acid, as we have seen, has a specific gravity of 1.832, (see §§ 31-36,) he should proceed exactly as indicated in § 38, and following; and the alkalimeter being filled with that test acid, of specific gravity 1.832 up to \( q \), it (the acid) should be poured carefully into the aqueous solution of the alkali tinged blue with litmus, until exact neutralization is attained, precisely in the same manner as in § 38, and following.

52. The neutralizing point being lit, let us suppose that the whole of the contents of the alkalimeter have been employed, that the aqueous solution tinged blue with litmus, is not yet saturated, and that, after having refilled the alkalimeter, the 4 divisions more (altogether 104 divisions) have been required to neutralize the alkali in the aqueous solution; then, since 100 divisions (1,000 water-grains measure) of the test acid now employed satu-
rate exactly one equivalent, that is, 47 of potash, the question is now, What quantity of potash will have been saturated by the 104 divisions of acid employed? The answer is found by a simple rule of proportion, to be nearly 49.

\[ 100 : 47 :: 104 : x = 48.88. \]

The sample of potash examined contained, therefore, nearly 49 per cent. of pure potash.

53. If, instead of the special test sulphuric acid for potash, (§ 47), or of the test sulphuric acid for potash, and other bases, (§ 28,) the operator uses the potash and soda alkalimeter, (§§ 31, 32,) the method to be followed is exactly similar to that described in § 42, and following. Some of the test sulphuric acid, of specific gravity 1.2938, is to be poured into the alkalimeter until it reaches the point marked "potash," (that is to say, 48.62 divisions of the alkalimeter,) taking the under line of the liquid as the true level, and the remaining divisions up to 0° are carefully filled with water. The operator then closes the aperture of the alkalimeter with the thumb of his left hand, and the whole is violently shaken so as to obtain a perfect mixture.

54. The acid so mixed must now be carefully poured from the alkalimeter into the alkaline solution of the potash under examination until neutralization is attained, precisely as described in § 42, and following.

55. The neutralizing point being hit, the operator allows the sides of the alkalimeter to drain, and he then reads off the number of divisions employed in the experiment, which number indicates the percentage of real potash contained in the sample.

56. Had the operator wished to estimate the quantity of potash as carbonate of potash, he should have poured the test acid into the alkalimeter up to the point marked "carbonate of potash," filled the remaining divisions of the alkalimeter up to 0° with water, and proceeding exactly as just mentioned, the number of divisions of acid employed would indicate the carbonate of potash contained in the sample as carbonate of potash.

57. If a Schütter's alkalimeter (fig. 15) is used, and supposing, for example, that the acid to be employed therewith is so adjusted that 10 grains' weight of i neutralize exactly 1 grain in weight of potash, proceed as follows:—Take 100 grains in weight of a fair average of the sample, previously reduced to powder, dissolve them in water, filter with the precautions which have already been described before, (§ 38, and following,) and pour this solution into a glass cylinder graduated into 100 parts, and capable of containing 10,000 parts, water-grains; fill it up with water exactly as described before; of this take now 100 alka-

58. When, however, potash is mixed with soda, as is frequently the case with the potash of commerce, either accidentally or for fraudulent purposes, the determination of the amount of the cheaper alkali could not, until a comparatively recent period, be estimated, except by the expensive and tedious process of a regular chemical analysis. In 1844, how-

59. The rationale of the method is grounded upon the increase of specific gravity which sulphate of soda produces in a solution saturated with pure sulphate of potash, and is deduced from the fact that a solution saturated with neutral sulphate of potash possesses a uniform and constant density when the saturation is made at the same temperature, and that the density of such a solution increases progressively in proportion to the quantity of sulphate of soda present; an increase of density so much the more readily observable, that the solubility of the sulphate of potash is greatly augmented by the presence of sulphate of soda. It had at first been thought that, in order to obtain any thing like accuracy, it would be necessary to combine all the potash with one same acid, preferably sulphuric acid; and, consequently, that as the potash of commerce always contains a little, and sometimes a rather considerable quantity, of chloride of potassium, the latter salt should first be decomposed. Further experiments, however, established the fact, that in dissolving chlor-

When soda is added to a saturated solution of sulphate of potash, the further
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addition of chloride of potassium thereto renders the specific gravity of the liquor less than it would have been without that addition—an apparent anomaly due to the fact that chlorine, in presence of sulphuric acid, of potash, and of soda, combines with the latter face to form chloride of sodium; and it is this salt which increases the solubility of sulphate of potash, though in a somewhat less degree than sulphate of soda. Thus, if to a saturated solution of sulphate of potash, 0.14 of soda be added along with 0.20 of chloride of potassium, the natrometer indicates only 0.125 of soda. Seeing, therefore, that in such an exceptional case the error does not amount to more than 0.015 of error, it will probably be found unnecessary in most cases to decompose the chloride contained in the potashes of commerce, that quantity being too small to materially affect the result. Yet, as the accurate determination of soda in potash was a great desideratum, M. Pesier contrived two processes, one of which, in the hands of the practised chemist, is as perfect as, but much more rapid than, those ordinarily resorted to; the other, which is a simplification of the first, yields results of sufficient accuracy for all commercial purposes.

60. First process.—Take 500 grains of a fair average sample of the potash to be examined, dissolve them in as little water as possible, filter, and wash the filter until the washings are no longer alkaline. This filtering, however, may be dispensed with when the potash is of good quality and leaves but a small residue, or when an extreme degree of accuracy is not required.

61. The potash being thus dissolved, a slight excess of sulphuric acid is added thereto; the excess is necessary to decompose the chlorides and sulphates of potash. The liquor so treated is then evaporated in a porcelain capsule, about six inches in diameter; and when it begins to thicken it should be stirred with a glass rod, in order to avoid projections. When dry, the fire must be urged until the residue fuses, and it is then kept in a state of tranquil fusion for a few minutes. The capsule should then be placed upon, and surrounded with hot sand, and allowed to cool down slowly, to prevent its cracking, which would happen without this precaution.

62. The fused mass in the capsule having become quite cold, should now be treated with as little hot water as possible, that is to say, with less than 3,000 grains of hot water; and this is best done by treating it with successive portions of fresh water. All the liquors thus successively obtained should then be poured into a flask capable of holding about 10,000 grains of water, and the excess of sulphuric acid must be accurately neutralized by a concentrated solution of pure carbonate of potash—that is to say, until the color of litmus-paper is no longer affected by the liquor, just as in ordinary alkalimetical or acidimetical assays. During this operation, a pretty considerable precipitate of sulphate of potash is, of course, produced.

63. The neutralizing point being exactly hit, a saturated solution of sulphate of potash is prepared, and brought to the atmospheric temperature; a condition which is expedited by plunging the vessel which contains the solution into a basin full of cold water, and stirring it until the thermometer plunged in the liquor indicates that the temperature of the latter is about the same as, and preferably less than, that of the air; because, in the latter case, it may be quite correctly adjusted by grasping the vessel with a warm hand. In order, however, to secure exactly the proper temperature, the whole should be left at rest for a few minutes after having withdrawn the vessel from the basin of cold water used for refrigerating it, taking care simply to stir it from time to time, and to ascertain that the thermometer remains at the same degree of temperature. This done, the liquor is filtered into a glass cylinder, c, on which a scratch, h-h, has been made, corresponding to 3,000 water-grains’ measure. If the directions given have been exactly followed, it will be found that the filtrate is not sufficient to fill it up to that mark; the necessary volume, however, should be completed by washing the deposit of sulphate of potash in the filter, n, with a saturated solution of the same salt (sulphate of potash) previously prepared. It is advisable to use a saturated solution of sulphate of potash which has been kept for some time, and not one immediately prepared for the purpose, because sulphate of potash, in dissolving, produces a certain amount of cold, which would create delay, since it would be necessary to wait until the temperature of the mass had become the same as that of the air.

64. The liquor occupying 3,000 water-grains’ measure in the cylinder, should be next rendered homogeneous by stirring it well, after which the natrometer may be immersed in
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53

it. The natrometer is simply an arcmeter of a peculiar construction, provided with two scales: the one of a pink color shows the degrees of temperature, and indicates, for each degree of the centigrade thermometer, the level at which a solution saturated with pure sulphate of potash would stand; on the other scale, each degree represents 1 per cent. of the solution, (oxide of sodium,) as represented in fig. 21.

55. The ° of the two scales coincide with each other. If the experiment take place at the temperature of °, the quantity of soda will be directly determined by observing the number of degrees on the soda scale; but if the experiment be performed at °, for example, it will be seen that the point at which the instrument would sink in the liquor saturated with pure sulphate of potash corresponds to ° of soda; and, in this case, it is from this point that the ° of the soda scale should be supposed to begin, which is easily accomplished by a simple subtraction, as will be seen presently.

56. Experiment having shown that the degrees of soda cannot be equidistant, but that, on the contrary, they become smaller and smaller as the quantity of soda increases, the number of degrees of soda are obtained as follows:—From the number of degrees of temperature now indicated on the pink scale of the natrometer, subtract the number of degrees of temperature indicated by an ordinary thermometer at starting; then look at the soda scale for the number of soda degrees which correspond to the number of degrees of temperature left after subtraction, and each of the soda degrees, beginning from the ° of the natrometer, represents 1 per cent.

57. For example:—Suppose the experiment to have been made at starting, and as indicated by an ordinary thermometer, at 20° centigrades, and that the level of the solution is now found to stand at 59° on the pink scale of temperature of the natrometer, then by deducting 20 (the original temperature) from 59 (number of degrees indicated by the floating point on the pink scale of temperatures of the natrometer) there remains, of course, 39. Draw the instrument out, and looking now on the pink scale for 59°, there will be found exactly opposite, on the soda scale, the number 13, which number signifies that the potash under examination contains 13 per cent. of soda, (oxide of sodium.)

58. At the degree of sulphate of potash separated by filtering might retain some sulphate of soda, it is advisable, in order to avoid all chance of error, to wash it with a saturated solution of sulphate of potash, adding as much of it as is necessary to bring the whole mass of the liquor up to the mark 3,000 water-grains' measures, in which the natrometer being again immersed, the minute quantity of soda indicated should be added to the percentage found by the first operation.

59. If a great degree of accuracy is required, the fractions of degree of the instrument must be taken account of; otherwise they may be neglected without the result being materially affected, since 2 degrees of the scale of temperature correspond only to about 1 per cent. of soda.

60. For commercial purposes, the process may be slightly varied, as follows:—Take 500 grains of a fair average sample of the potash to be examined, previously reduced to powder, and throw them into a flask (fig. 22) capable of containing about 6,000 grains of water; pour upon them about 2,000 grains of water, and shake until dissolved. Add now sulphuric acid thereto; this will produce a smart effervescence, and in all probability a deposit of sulphate of potash. We say in all probability, because it is clear that if the potash in question is largely adulterated with soda, or was altogether nothing else than carbonate of soda, as has occasionally happened, it is evident that no deposit of sulphate of potash would take place; and yet, as it is necessary to the success of the operation that the liquor should contain an excess of this latter salt, a certain quantity of it previously reduced to fine powder must in that case be purposely added to the solution.

61. After the disengagement of gas has ceased, it is necessary to pour the dilute acid cautiously, and only drop by drop, until the neutralizing point is correctly hit, which will be known as usual by testing with litmus-paper. But if, by accident, too much acid has been used, which is known by the reddening of the litmus-paper, the slight overdose may be neutralized by adding a small quantity of weak solution of potash.

62. As this reaction produces heat, it is necessary to lower the liquor down to the temperature of the atmosphere, decont in a filter placed over the glass cylinder, and fill it up to the scratch 3,000, by washing the residue on the filter with a saturated solution of sulphate of potash, exactly as described in § 63.

63. The glass cylinder being properly filled up to the scratch, remove the funnel, close the orifice of the glass cylinder with the palm of the hand, and shake the whole violently.
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holding the natrometer, which should be perfectly clean, by its upper extremity, slowly immerse it in the solution. If the potash under examination be pure, the pink scale will indicate the degree of temperature at which the experiment has been made, taking the under line as the true level of the liquid; but if, on the contrary, it contains soda, the pink scale of temperatures will indicate a few degrees more than the real temperature, and this surplus number of degrees, being compared with those of the soda scale contiguous to it, on the opposite side, will express the percentage of soda present in the sample.

For example:—Suppose the experiment to have been made at + 13° centigrade, and to have given a solution marking 25° on the pink scale of temperatures of the natrometer, that is, 13° more than the real temperature;—looking therefore at number 13 on the pink scale of temperature, it will be seen that the number exactly opposite on the soda scale, and corresponding to it, is 4, which indicates that the sample of potash examined contains 4 per cent. of soda.

It is important to bear in mind that all commercial potashes contain naturally a small quantity of soda, which quantity, in certain varieties, may even be considerable; it is only when the proportion of soda is more considerable than that which is naturally contained in the species of potash submitted to analysis, that it should be considered as fraudulently added. The following table, published by M. Pesier, shows the average composition of the principal varieties of potash found in commerce, when in an unadulterated state.

**Average Composition of Potashes.**

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</thead>
<tbody>
<tr>
<td>Sulphate of potash</td>
<td>34-93</td>
<td>34-35</td>
<td>18-38</td>
<td>38-84</td>
<td>4-72</td>
<td>2-99</td>
<td>16-19</td>
</tr>
<tr>
<td>Chloride of potassium</td>
<td>2-99</td>
<td>2-90</td>
<td>8-45</td>
<td>3-64</td>
<td>9-10</td>
<td>18-17</td>
<td>19-00</td>
</tr>
<tr>
<td>Carbonate of potash</td>
<td>71-99</td>
<td>69-91</td>
<td>69-97</td>
<td>72-10</td>
<td>38-63</td>
<td>38-63</td>
<td>33-90</td>
</tr>
<tr>
<td>Carbonate of soda (dry)</td>
<td>3-90</td>
<td>3-58</td>
<td>3-23</td>
<td>4-31</td>
<td>4-31</td>
<td>24-41</td>
<td>25-17</td>
</tr>
<tr>
<td>Insoluble residue</td>
<td>0-65</td>
<td>1-21</td>
<td>3-53</td>
<td>0-94</td>
<td>2-60</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Moisture</td>
<td>7-23</td>
<td>8-32</td>
<td>under-</td>
<td>4-52</td>
<td>5-54</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Phosphoric acid, lime, silica, &amp;c.</td>
<td>0-54</td>
<td>1-97</td>
<td>d.</td>
<td>2-28</td>
<td>1-20</td>
<td>1-56</td>
<td>0-92</td>
</tr>
<tr>
<td>Alkalimetric degrees</td>
<td>10-00</td>
<td>10-00</td>
<td>10-00</td>
<td>10-00</td>
<td>10-00</td>
<td>10-00</td>
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75. The alkalimetric assay of soda is performed exactly in the same manner as that of potash—that is to say: From a fair average sample of the soda to be examined, take 1,000 grains' weight, (or less, if that quantity cannot be spared) and boil it five or six minutes in about eight fluid ounces of water; filter, in order to separate the insoluble portion, and wash the residue on the filter with boiling water until it no longer drops from the filter with an alkaline reaction, and the bulk of the filtered liquid and the washings received in a graduated glass cylinder form 10,000 grains' measure. Should the water which may have been required to wash the residue have increased the bulk of the solution beyond that quantity, it should be evaporated to reduce it to the bulk mentioned.

76. This being done, 1,000 water-grains' measure—that is to say, 1/10 part of the aqueous solution of the soda ash above mentioned (§ 75)—is transferred to the glass beaker or vessel in which the saturation is intended to take place, it is tinged distinctly blue with tincture of litmus, and the operation is performed in the same manner and with the same precautions as for potash; the glass beaker containing the blue alkaline solution being placed upon a sheet of white paper, or a slab of white porcelain, the better to observe the change of color which takes place when the saturating point is approaching.

77. Having put into a glass beaker the 1,000 grains' measure of the aqueous solution of soda ash to be examined, (§ 75) and of the test sulphuric acid for soda, described before, (§§ 23-27,) the alkalimeter, flos. 12, 13, 14, should be filled with that test acid up to the point marked 0°, (taking the under line of the liquid as the true level,) and poured therefrom with the precaution already indicated, stirring briskly, at the same time, the liquid is: the beaker. As is the case with the alkalimetric assay of potash, the carbonic acid expelled

*In the impossibility of estimating exactly the loss by calculation, and the quantity of oxide of potassium in the caustic state, (hydrate of potash,) we have reduced the potash to the state of carbonic acid, to make comparison more easy.
by the test acid reacting upon the as yet undecomposed portion of the soda ash, converts it into bicarbonate of soda, so that at first no effervescence is produced; but as soon as half the quantity of the soda in the solution is saturated, a brisk effervescence takes place. At first, therefore, the operator may pour at once, without fear, a pretty large quantity of the test acid into the alkalimetric solution, but as soon as this effervescence makes its appearance, he should proceed with increased precaution gradually as the saturating point is approached. The modus operandi is, in fact, precisely as already detailed for the assay of potash, precisely the same kind and amount of care is requisite, and the assay is known to be terminated when the streaks made upon the litmus-paper with the stirring rod remain distinctly and permanently of a pink color.

78. After saturation, and after having allowed the sides of the alkalimeter to drain, the number of divisions at which the test acid stands in the alkalimeter indicate at once the percentage of the soda assayed, since, as we said, each division of this particular test acid represents one grain of pure soda. If, therefore, the test acid stands at 52 in the alkalimeter, then the soda assayed contained 52 per cent. of real soda. See, besides, the observations of § 48 and following, and also § 81.

79. If, instead of the special test acid for soda just alluded to, the operator employs that which has a specific gravity of 1.032, and 100 alkalimetric divisions of which saturate one equivalent of each base, the modus operandi is the same—that is to say, the alkalimeter is filled with it up to 0°, and it is poured therefrom carefully into the alkalimetric solution; but as the equivalent of soda is 31, and 100 alkalimetric divisions of the test sulphuric acid now employed are capable of saturating only that quantity of soda, it is clear that with the soda ash taken as an example in the preceding case, and containing 52 per cent. of real soda, the operator will have to refill his alkalimeter with the same test acid, and that a certain number of divisions of this second filling will have to be employed to perfect the saturation.

In this instance the operator will find that nearly 68 divisions more, altogether 168 divisions (correctly, 167.7) have been required to effect the saturation, as with the actual test acid employed, the point of saturation is reached with the same 52 divisions or divisions.

80. If, instead of the special test sulphuric acid for soda, (§§ 23–27,) or the test sulphuric acid for potash, soda, and other bases, (§§ 31–34,) the operator uses the potash and soda alkalimeter, (§§ 28–35,) the method is always the same (§§ 74, 75)—that is to say, the aqueous solution of the soda ash is poured into the glass beaker, the difference being merely that instead of the alkalimeter being quite filled up with the test sulphuric acid, which, in the present instance, has a specific gravity of 1.268 (§ 29), the said test acid is poured into the alkalimeter only up to the point marked "soda," (taking the under line of the liquid as the true level,) and the remaining divisions of the alkalimeter are carefully filled up with water. The mouth of the tube should then be thoroughly closed with the thumb of the left hand, and the whole violently shaken until perfectly mixed, taking great care, of course, not to squirt any of the acid out of the tube, which evidently would cause an amount of error proportionate to the quantity of the test acid which would have thus been lost. The acid should then be poured from the alkalimeter with the usual precaution (§ 70) into the glass beaker containing the aqueous solution of the soda ash under examination, until complete neutralization is attained, stirring briskly all the time, or after each addition of the test acid. The neutralization point being hit, the sides of the alkalimeter are allowed to drain, and the operator then reads off the number of divisions, which, as before, indicates the percentage of real soda contained in the sample assayed. Thus, if the sample operated upon be the same as that alluded to before, the number of divisions employed being 52 would indicate 52 per cent. of real soda.

81. If the operator wishes to estimate the amount of soda in the sample as carbonate of soda, fill the alkalimeter with the test acid. In question (specific gravity 1.268) up to the point marked carbonate of soda, and fill the remaining divisions with water, shake the whole well, and proceed with the neutralization of the aqueous solution of the sample in the glass beaker as just described. Supposing, as before, that the sample in question contains 52 per cent. of real soda, it will now be found that the number of divisions employed altogether to saturate the sample completely are very nearly 89, for 52 of caustic soda correspond to 88-90 of the carbonate of that alkali.

82. If the soda ash is very poor, instead of operating upon 1,000 water-grains' measure, or one-tenth part of the whole solution, (= 100 grains' weight of the soda ash, §§ 76–77,) it is advisable to take three or four thousand water-grains' measure of the alkalimetric solution, and to divide, by three or four, the result obtained by saturation. Suppose, for example, that the quantity of real soda found is 46; this, if only 1,000 grains' measure had been taken, would, of course, indicate 46 per cent.; but as 4,000 water-grains' measure of solution has been taken instead, that number 46 must, accordingly, be divided by 4, which gives 11 per cent. only of real soda contained in the sample under examination.

83. The soda ash of commerce contains generally a percentage of insoluble substances, which are removed by filtering, as we said, and a greater or less quantity of chloride of sodium (common salt) and carbonate of soda, which, however, do not in the slightest degree interfere with the accuracy of the result. But there is a source of error resulting from the
ALKALIMETRY.

presence in the soda ash of sulphuret of calcium, of sulphite, and sometimes also, though more rarely, of hyposulphite, of soda. When sulphuret of calcium is present in the ash, on heating the latter by hot water, a double decomposition takes place, the sulphuret of calcium, reacting upon the carbonate of soda, forms sulphuret of sodium and carbonate of lime. Now sulphuret of sodium saturates the test acid just as carbonate of soda; but as it has no commercial value, it is clear that if the ash contains a quantity of the useless sulphuret at all considerable, a very serious damage may be sustained by the purchaser if the percentage of this substance present in the ash be taken account of as being soda. Sulphuret of soda is produced from the oxidization of this sulphuret of sodium, and is objectionable inasmuch that, when the test acid is added slowly to the aqueous solution of the ash, the effect is to convert the sulphite into bisulphite of soda, before any evolution of sulphuric acid, and consequently before the pink reaction on litmus-paper is produced.

84. In order to obviate the inaccuracies resulting from the neutralization of a portion of the test acid by these substances, it is necessary to convert them into sulphates of soda, which is easily done by calcining a quantity of the sample with five or six per cent. of chloride of potash, as recommended by Gay-Lussac and Welther. The operator, therefore, should intimately mix 80 or 60 grains' weight of pulverized chloride of potash with 1,000 grains of the pulverized sample, and fuse the mixture in a platinum crucible, for which purpose a blowpipe gas-furnace will be found exceedingly convenient. The fused mass should be washed, and the filtrate being received into a 10,000 water-grains' measure, and made up with water to occupy that bulk, may then be assayed in every respect as described before with one or other of the test acids mentioned.

85. When, however, the soda ash contains some hyposulphite of soda—which fortunately is seldom the case, for this salt is very difficultly produced in presence of a very large excess of alkali—one should not be calcined with chloride of potash, because that one equivalent of hyposulphite becomes transformed not into one equivalent of sulphate, but, reacting upon one equivalent of carbonate of soda, expels its carbonic acid, and forms with the soda of the decomposed carbonate a second equivalent of sulphate of soda, each equivalent of hyposulphite becoming thus converted into two equivalents of sulphate, and therefore creating an error proportionate to the quantity of the hyposulphite present, each equivalent of which would thus destroy one equivalent of real and available alkali, and thus render the estimation of the sample inaccurate, and possibly to a very considerable extent.

86. When this is the case, it is therefore advisable, according to Meers, Fordos and Gelis, to change the condition of the sulphurets, sulphites, and hyposulphites, by adding a little neutral chromate of potash to the alkaline solution, whence result sulphate of chromium, water, and a separation of sulphur, which will not affect the accuracy of the alkaliometrical process.

87. Whether the sample to be analyzed contains any sulphuret, sulphite, or hyposulphite, is easily ascertained as follows:—If, on pouring sulphuric acid upon a portion of the sample of soda ash under examination, an odor of sulphuretted hydrogen—that is, an odor of rotten eggs—is evolved, or if a portion of the soda ash, being dissolved in water, and then filtered, produces a black precipitate (sulphuret of lead) when solution of acetate of lead is poured into it, then the sample contains a sulphuret.

88. And if, after adding to some dilute sulphuric acid as much bichromate of potash as is necessary to impart to it a distinct reddish-yellow tinge, and a certain quantity of the solution of the soda ash under examination being poured into it, but not in sufficient quantity to neutralize the acid, the reddish-yellow color becomes green, it is a proof that the sample contains either sulphite or hyposulphite of soda, the green tinge being due to the transformation of the chromic acid into sesquisoxide of chromium.

89. And if, muriatic acid being poured into the clear solution of the soda ash, a turbidity supervenes after some time if left at rest, or at once if heat is applied, it is due to a deposit of sulphur, an odor of sulphuric acid being evolved, and hyposulphite of soda is probably present. We say probably, because if sulphurets and sulphites are present, the action of muriatic acid would decompose both, and liberate sulphuretted hydrogen and sulphuric acid; but as these two gases decompose each other, a turbidity due to a separation of sulphur is also formed; thus 2H₂S + S O₂ = 2H₂O + 2S.

90. As we have already had occasion to remark, the soda ash of commerce frequently contains some, and occasionally a large quantity of caustic soda, the proportion of which is at times important to determine. This may be done, according to Mr. Barre, by adding a solution of chloride of barium to the aqueous solution of the soda ash, by which the carbonate of soda is converted into carbonate of barytes, whilst the caustic soda, reacting upon the chloride of barium, liberates a quantity of caustic barytes proportionate to that of the caustic soda in the soda ash. After this addition of chloride of barium, the liquor is filtered, the precipitated carbonate of barium being removed, and which remains on the filter, on which it should be washed with pure water. A few lumps of chalk are then put into a Florence flask, a, and some muriatic acid being poured upon it, an effervescence due to a disengagement of carbonic acid is produced, the flask is then closed
with a good cork, provided with a bent tube, b, reaching to the bottom of the vessel, c, and the stream of carbonic acid produced is then passed through the liquor, e, filtered from the carbonate of barytes above mentioned. The stream of carbonic acid produces a precipitate of carbonate of barytes, which should be also collected on a separate filter, washed, dried, and weighed. Each gain of this second precipitate of carbonate of barytes corresponds to 0.3157 of caustic soda.

91. As the soda ash of commerce almost invariably contains earthy carbonates, the sample operated upon should always be dissolved in hot water, and filtered, in order to separate the carbonate of lime, which otherwise would saturate a proportionate quantity of the test acid, and thus render the analysis worthless.

92. The quantity of water contained in either potash or soda ash is ascertained by heating a weighed quantity of the sample to redness in a covered platinum capsule or crucible. The loss after ignition indicates the proportion of water. If any caustic alkali is present, 1 equivalent, = 9 of water, is retained, which cannot be thus eliminated, but which may, of course, be determined by calculation after the proportion of caustic soda has been found, as shown before, each 31 grains of caustic soda containing 9 grains of water.

93. Besides the alkalimetrical processes which have been explained in the preceding pages, the proportion of available alkali contained in the sample may be estimated from the amount of carbonic acid which can be expelled by supersaturating the alkali with an acid. The determination of the value of alkalis, from the quantity of carbonic acid thus evolved by the supersaturation of the carbonate acted upon, has long been known. Dr. Ure, in the "Annals of Philosophy," for October, 1817, and then in his "Dictionary of Chemistry," 1821, and more recently in his pamphlet "Chemistry Simplified," described several instruments for analyzing earthy and alkaline carbonates, for a description of which the reader is referred to the article on Acidimetry. The ingenious little apparatus of Drs. Fresenius and Will's for the same purpose, and to which we have already alluded in the same article, gives accurate results; but it should be observed that when the potash or soda of commerce contains any caustic alkali, or bicarbonate, or earthy carbonates, or sulphuret of alkali—which, as we have seen, is frequently, and, indeed, almost invariably, the case, the process is no longer applicable without first submitting the sample to several operations—which render this process troublesome and unsuited to unpractised hands. Thus, if caustic potash is present, the sample must be first mixed and triturated with its own weight of pure quartzose sand and about one-third of its weight of carbonate of ammonia. The mass is then moistened with aqueous ammonia, and then put into a small iron capsule and evaporated to dryness. The capsule is then removed, and the ammonia and carbonate of ammonia are then washed out by water, filtered, washed, and concentrated to a proper bulk by evaporation, transferred to the apparatus, and treated as will be seen presently. If the sample contains caustic soda, instead of one-third, at least half of its weight of carbonate of ammonia should be employed. But for the estimation of pure carbonates, Drs. Fresenius and Will's method is both accurate and easy. The apparatus consists of two flasks, a and b; the first should have a capacity of from two to two ounces and a half; the second, or flask n, should be of a somewhat smaller size, and hold about one and a half or two ounces. Both should be provided with perfectly sound corks, each perforated with two holes, through which the tubes a, c, d, are passing. The lower extremity of the tube a must be adjusted so as to reach nearly to the bottom of the flask a, and its upper extremity is closed by means of a small pellet of wax; b, e is a tube bent twice at right angles, one end of which merely protrudes through the cork into the flask a, but the other end reaches nearly to the bottom of the flask n. The tube d of the flask n merely protrudes through the cork into the flask.
a few air-bubbles, which, as the other tube, \( a \), is closed by the wax pellet, rarefies the air in the flask \( a \), and consequently causes the sulphuric acid of flask \( a \) to ascend a certain height (after the suction) into the tube \( e \); and if, after a short time, the column of sulphuric acid maintains its height in the tube \( e \), it is a proof that the apparatus is air-tight, and therefore as it should be. This being ascertained, suction is again applied to the extremity of the tube \( d \), so that a portion of the sulphuric acid of the flask \( b \) ascends into the tube \( e \), and presently falls into the flask \( a \); the quantity which thus passes over being, of course, proportionate to the vacuum produced by the suction. As soon as the acid thus falls in the water containing the alkaline carbonate in the flask \( a \), an effervescence is immediately produced, and as the carbonic acid disengaged must, in order to escape, pass, by the tube \( e \), through the concentrated sulphuric acid of the flask \( b \), it is thereby completely dried before it can finally make its exit through the tube \( d \). The effervescence having subsided, suction is again applied to the tube \( d \), in order to cause a fresh quantity of sulphuric acid to flow over into the flask \( a \), as before; and so on, till the last portion of sulphuric acid sucked over produces no effervescence, which indicates, of course, that all the carbonate is decomposed, and that, consequently, the operation is at an end. A powerful suction is now applied to the tube \( d \), in order to cause a tolerably large quantity of sulphuric acid, but not all, to flow into the flask \( a \), which thus becomes very hot, from the combination of the concentrated acid with the water, so that the carbonic acid is thereby thoroughly expelled from the solution. The little wax pellet which served as a stopper is now removed from the tube \( e \), and suction applied for some time, in order to sweep the flasks with atmospheric air, and thus displace all the carbonic acid in the apparatus, which is allowed to become quite cold, and weighed again, together with the wax pellet, the difference between the first and the second weighing—that is to say, the loss—indicates the quantity of carbonic acid which was contained in the carbonate, which has escaped, and from which, of course, the quantity of the carbonated alkali acte upon may be calculated. Suppose, in effect, that the loss is 19 grains; taking the

\[
\text{Equivalent of soda} \quad = \quad 31 \\
\text{carbonic acid} \quad = \quad 22 \\
1 \text{ equivalent of carbonate of soda} \quad = \quad 53,
\]

it is clear that the 19 grains of carbonic acid which have been expelled represent 45\,77 grains of carbonate of soda, or, in other words, 100 grains of soda ash operated upon contained 45\,77 of real carbonate of soda, this:

\[
\begin{align*}
\text{CO}_2 & : \text{Na}_2\text{O} & \text{CO}_2 & : \text{CO}_2 \\
22 & : & 53 & : & 19 & : & x & = & 45\,77
\end{align*}
\]

95. As the soda ash of commerce always contains earthy carbonates, and very frequently sulphures, and occasionally hyposulphites, instead of putting the 100 grains to be operated upon directly into the flask \( a \), it is absolutely necessary first to dissolve them in boiling water, to filter the solution, and to wash the precipitate which may be left on the filter with boiling water. The solution and the washings being mixed together, should then be reduced by evaporation to a proper volume for introduction into the flask \( a \), and the process is then carried on as described. If sulpharet, sulphures, or hyposulphites are present, the ash should be treated exactly as mentioned in §§ 83-91, previous to pouring the solution into the flask \( a \), since otherwise the sulphured hydrogen and sulphurous acid, which would be disengaged along with the carbonic acid, would apparently augment the proportion of the latter, and render the result quite erroneous.

96. The balance used for this mode of analysis should be capable of indicating small weights when heavily laden.—A. N.

**ALKALINE EARTHS.—Barites, Lime, and Strontia.** These earths are so called to distinguish them from the earths Magnesia and Alumina. They are soluble in water, but to a much less extent than the alkalies. Their solutions impart a brown color to turneric paper, and neutralize acids. They are, however, distinguished from the alkalies by their combination with carbonic acid, being nearly insoluble in water.

AL-KENNA, or AL-HENNA, is the name of the root and leaves of Lawsonia inermis, which have been long employed in the East to dye the nails, teeth, hair, garments, &c. The leaves, ground, and mixed with a little lime-water, serve for dyeing the tails of horses in Persia and Turkey.

It is the same as the herb Henna frequently referred to by the Oriental poets. The powder of the leaves, being wet, forms a paste, which is bound on the nails for a night, and the color thus given will last for several weeks.

This plant is sometimes called the true alkamet root, the alkamet of the shops being termed the spurious alkamet root, (radix alkamna sparice.)

**ALLIOLE.** One of the hydrocarbons which can be obtained from naphtha. It is one of the most volatile of bodies. Alliole is obtained by distilling crude naphtha, and collect-
ALLOY 59

ing all that leaves the still in the first distillation before the boiling temperature reaches 194° F; and on the second distillation, all below 176° F. This substance combines with, or is altered by, oil of vitriol, and hence it is better obtained from the crude naphtha, and afterwards purified by agitation with dilute sulphuric or hydrochloric acid, and redistillation. It boils, when nearly free from brecule, at a temperature of from 140° to 158° F., and possesses an allaceous odor somewhat resembling sulphide of carbon.—Richardson.

ALLOTROPY. Allotropic Condition. A name introduced by Berzelius to signify another form of the same substance, derived from ἀλλαθέος, another, and τρόπος, habit. Carbon, for example, exists as the diamond, a brilliant gem, with difficulty combustible; as graphite, a dark, heavy, opaque mass, often crystalline, also of great insusibility; and as charcoal, a dark porous body, which burns with facility.

An extensive series of bodies appears to assume similar allotropic modifications. The probability is that, with the advance of physical and chemical science, many of the substances now supposed to be elementary will be proved to be but allotropic states of some one form of matter. Deville has already shown that silicon and boron exist, like the diamond, in three allotropic states—one of the conditions of boron being much harder than the diamond.

ALLOY. The experiments of Crookewitt upon amalgams appear to prove that the combination of metals in alloys obeys some laws of a similar character to those which prevail between combining bodies in solution; i.e., that a true combining proportion existed.

By amalgamation and straining through chamois leather, he obtained crystalline metallic compounds of gold, bismuth, lead, and cadmium, with mercury, which appeared to exist in true definite proportions. With potassium he obtained two amalgams, K\textsubscript{2}Hg\textsubscript{2} and K\textsubscript{3}Hg. With silver, by bringing mercury in contact with a solution of nitrate of silver, according to the quantity of mercury employed, he obtained such amalgams as Ag \textsubscript{2}Hg, Ag \textsubscript{3}Hg, Ag \textsubscript{5}Hg, Ag \textsubscript{9}Hg.

Beyond these there are many experiments which appear to prove that alloys are true chemical compounds; but, at the same time, it is highly probable that the true chemical alloy is very often dissolved (mechanically disseminated) in that metal which is largely in excess.

Some years since, the editor carried out an extensive series of experiments in the laboratory of the Museum of Practical Geology, with the view of obtaining a good alloy for soldiers' medals, and the results confirmed his views respecting the laws of definite, proportional combination among the metals. Many of those alloys were struck at the Mint, and yielded beautiful impressions; but there were many objections urged against the use of any alloy for a medal of honor.

The alloys of the following metals have been examined by Crookewitt, and he has given their specific gravities as in the following table; the specific gravity of the unalloyed metals being—

<table>
<thead>
<tr>
<th>Metal</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>8.974</td>
</tr>
<tr>
<td>Tin</td>
<td>7.305</td>
</tr>
</tbody>
</table>

That of the alloys was—

<table>
<thead>
<tr>
<th>Metal</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu \textsubscript{2} Sn</td>
<td>7.652</td>
</tr>
<tr>
<td>Cu Sn</td>
<td>8.072</td>
</tr>
<tr>
<td>Cu Sn</td>
<td>8.312</td>
</tr>
<tr>
<td>Cu Zn</td>
<td>7.934</td>
</tr>
<tr>
<td>Cu Zn</td>
<td>8.224</td>
</tr>
<tr>
<td>Cu Pb</td>
<td>8.392</td>
</tr>
<tr>
<td>Cu Pb</td>
<td>10.733</td>
</tr>
</tbody>
</table>

There are many points of great physical as well as chemical interest in connection with alloys, which require a closer study than they have yet received. There are some striking facts, brought forward by M. Wertheim, deduced from experiments carried on upon fifty-four binary alloys and nine ternary alloys of simple and known composition, which will be found in the "Journal of the French Institute," to which we would refer the reader.

On the Melting Point of Certain Alloys.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Centigrade Thermometer.</th>
<th>Lead, 2 atoms; lead, 1 atom</th>
<th>Tin, 2 atoms; lead, 1 atom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu Sn</td>
<td>335°</td>
<td>196°</td>
<td></td>
</tr>
<tr>
<td>Cu Sn</td>
<td>250°</td>
<td>241°</td>
<td></td>
</tr>
<tr>
<td>Cu Zn</td>
<td>194°</td>
<td>241°</td>
<td></td>
</tr>
<tr>
<td>Cu Pb</td>
<td>189°</td>
<td>241°</td>
<td></td>
</tr>
</tbody>
</table>

In these experiments of M. Kupfli, the temperatures were determined with thermom-
ALLOY.

eters of great delicacy, and the weighings were carefully carried out.—Ann. de Chimie, xl. 285—302; Brewer's Edin. Jour. Sci. 1. N.S. p. 299.

It may prove convenient to give a general statement of the more striking peculiarities of the important alloys. More detailed information will be found under the heads of the respective metals.

Gold and Silver Alloys.—The British standard for gold coin is 22 parts pure gold and 2 parts alloy; and for silver, 222 parts pure silver to 18 parts of alloy.

The alloy for the gold is an indefinite proportion of silver and copper; some coin has a dark red color, from the alloy being chiefly copper; the lighter the color a larger proportion of silver is indicated, sometimes even (when no copper is present) it approaches to a greenish tinge, but the proportion of pure gold is the same in either case.

The alloy for silver coinage is always copper; and a very pure quality of this metal is used for alloying, both for the gold and silver coinage, as almost any other metal being present, even in very small quantities, would make the metals unfit for coinage, from rendering the gold, silver, and copper brittle, or not sufficiently malleable.

The standard for plate (silver) is the same as the coin, and requires the same quantity of copper, and carefully melting with two or three bits of charcoal on the surface while in fusion, to prevent the oxidation of the copper by heat and exposure to the atmosphere.

The gold standard for plate and jewellery varies, by a late act of Parliament, from the 22 carats pure, to 18, 12, and 9: the alloys are gold and silver, in various proportions, according to the taste of the workmen: the color of the articles manufactured depending, as with the coin, on the proportions; if no copper is used in qualities under 22 carats fine gold, the color varies from a soft green to a greenish white, but a proportion of copper may be used so as to bring the color to nearly that of 22 fine, 1 silver, and 1 copper.

Wire of either gold or silver may be drawn into very fine wire, for fine purposes, such as lace, contains from 5 to 9 pennyweights of copper in the pound of 249 pennyweights, to render it not so soft as it would be with pure silver.

Gold, silver, and copper, may be mixed in any proportions without injury to the ductility, but no reliable scale of tenacity appears to have been constructed, although gold and silver in almost any proportions may be drawn to the very finest wire.

Gold and palladium may be made in any proportions; it has been found that even 3 per cent. of palladium prevents silver tarnishing so soon as without it; 10 per cent. very considerably protects the silver, and 30 per cent. of palladium will prevent the silver being affected by fumes of sulphurised hydrogen unless very long exposed: the latter alloy has been found useful for dental purposes, and the alloy with less proportions—say 10 to 15 per cent.—has been used for graduated scales of mathematical instruments.

The alloy of platinum and silver is made for the same purposes as those of palladium, and, by proper care in fusion, are nearly equally useful, but the platinum does not seem to so perfectly combine with the silver as the palladium. Any proportion of palladium with gold injures the color, and even 1 per cent. may be detected by sight, and 5 per cent. renders it a silver color, while about 10 per cent. destroys it; but the ductility of the alloy is not much injured.

Gold leaf for gilding contains from 3 to 12 grains of alloy to the ounce. Sixteen-carat gold, which is 3 fine gold and 2 alloy, the alloy being nearly always equal proportions of silver and copper, is not in the slightest degree injurious for dentists' purposes.

Antimony in the proportion of \( \frac{1}{4} \) quite destroys the ductility of gold.

Gold and platinum alloy forms a somewhat elastic metal. Hermsthal's imitation of gold consists of 16 parts of platinum, 7 parts of copper, and 1 of zinc, put in a crucible, covered with charcoal powder, and melted into a mass.—P. J.

Dentists' amalgam is prepared by rubbing together, in a mortar, or even in the hollow of the hand, finely divided silver and mercury, and then pressing out all the uncombined mercury. This alloy, when put into the hollow of a decayed tooth, very soon becomes exceedingly hard. Some dentists add a little copper, or gold, or platinum leaf, under the impression that the amalgam becomes harder.

Copper Alloys.—Copper alloyed with zinc forms Brass, and with tin, we have Bronze. (See those articles.) The alloys of the ancients were usually either brasses or bronzes. The following analyses of ancient coins, &c., by Mr John Arthur Phillips, are of great value.

It is not a little curious to find that some of the coins of high antiquity contain zinc, which does not appear to have been known as a metal before 1280 A.D., when Albertus Magnus speaks of zinc as a semi-metal, and calls the alloy of copper and zinc golden auracite; or rather, perhaps, he meant to apply that name to zinc, from its power of imparting a golden color to copper. The probability is that calamine was known from the earliest times as a peculiar earth, although it was not thought to be an ore of zinc, or of any other metal.

—See Watson's Chemical Essays.
Copper, when united with half its weight of lead, forms an inferior alloy, resembling gun-metal in color, but is softer and cheaper. This alloy is called pot-metal and cock-metal, because it is used for large measures and in the manufacture of tap-rods of all descriptions.

Sometimes a small quantity of zinc is added to pot-metal; but when this is considerable, the copper seizes the zinc to form brass, and leaves the lead at liberty, a large portion of which separates on cooling. Zinc and lead are not disposed to unite; but a little arsenic occasions them to combine.

Of the alloys of copper and lead, Mr. Holtzapffel gives the following description:

**LEAD ALLOYS.**—Two ounces lead to one pound copper produce a red-colored and ductile alloy.

Four ounces lead to one pound copper give an alloy less red and ductile. Neither of these is so much used as the following, as the object is to employ as much lead as possible.

Six ounces lead to one pound copper is the ordinary pot-metal, called dry pot-metal, as this quantity of lead will be taken up without separating on cooling; this alloy is brittle when warmed.

Seven ounces lead to one pound copper form an alloy which is rather short, or disposed to break.

Eight ounces lead to one pound copper is an inferior pot-metal, called wet pot-metal, as the lead partly coalesces out in cooling, especially when the new metals are mixed; it is therefore always usual to fill the crucible in part with old metal, and to add new for the remainder. This alloy is very brittle when slightly warmed. More lead can scarcely be used, as it separates on cooling.

Antimony twenty parts and lead eighty parts form the printing-type of France; and lead and antimony are united in various proportions to form the type-metal of our printers. See Type.

Mr. James Nasmyth, in a letter to the "Athenaeum," (No. 1176, p. 511), directed attention to the employment of lead, and its fitness as a substitute for all works of art hitherto executed in bronze or marble. He says the addition of about 5 per cent. of antimony to the lead will give it, not only great hardness, but enhance its capability to run into the most delicate details of the work.

Baron Wetterstedt's patent sheathing for ships consists of lead, with 2 to 8 per cent. of antimony; about 3 per cent. is the usual quantity. The alloy is rolled out into sheets. Holtzapffel. We are not aware that this alloy has ever been employed.
ALLOY.

Emery wheels and grinding tools for the lapidary are formed of an alloy of antimony and lead.

Organ pipes are sometimes made of lead and tin, the latter metal being employed to harden the lead. The pipes, however, of the great organ in the Town Hall of Birmingham are principally made of sheet zinc.

Lead and arsenic form shot-metal. The usual proportions are said to be 40 lbs. of metallic arsenic to one ton of lead.

Tabular Statement of the Physical Peculiarities of the Principal Alloys, adopted, with some alterations, from the "Encyclopédie Technologique."

<table>
<thead>
<tr>
<th>BRITTLE METALS.</th>
<th>ARSENIC.</th>
<th>ANTIMONY.</th>
<th>BISMUTH.</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Zinc, rendering it brittle.</td>
<td>This alloy is very brittle.</td>
<td>Unknown.</td>
<td>Doubtful.</td>
</tr>
<tr>
<td>With Iron and Steel, hardening, whitening, and rendering those metals susceptible of a fine polish; much used for steel chains and other ornaments.</td>
<td>30 of iron and 70 of antimony are fusible; very hard, and white. An alloy of two of iron and one of antimony is very hard and brilliant.</td>
<td>Forms readily a pale-yellow alloy, breaking with a fracture like porcelain.</td>
<td>Similar to antimony; of a yellow-green color.</td>
</tr>
<tr>
<td>With Gold, a gray metal, very brittle.</td>
<td>Alloys readily; the alloys are brittle. Those formed with equal parts of the two metals are of a fine violet color.</td>
<td></td>
<td>Pale-red brittle metal.</td>
</tr>
<tr>
<td>With Copper. Composed of 62 parts of copper and 38 arsenic, a gray, brilliant, brittle metal. Increasing the quantity of copper, the alloy becomes white and slightly ductile; used in the manufacture of buttons under the name of white copper, or Tombac.</td>
<td>These have a strong affinity; their alloys are always brittle.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Silver. 23 of silver and 14 of arsenic form a grayish-white brittle metal.</td>
<td>Antimony gives hardness to lead. 24 parts of antimony and 76 of lead, corresponding to PbSb, appear the point of saturation of the two metals.</td>
<td>Alloys brittle and lamellated.</td>
<td>The alloys of bismuth and lead are less brittle and more ductile than those with antimony; but the alloy of 3 parts of lead and 2 of bismuth is harder than lead. These alloys are very fusible.</td>
</tr>
<tr>
<td>With Lead. Arsenic renders lead brittle. The combination is very intimate; not decomposed by heat.</td>
<td>The alloys of antimony and tin are very white. They become brittle when the arsenic is in large quantity.</td>
<td></td>
<td>Tin and bismuth unite in all proportions by fusion. All the alloys are more fusible than tin.</td>
</tr>
<tr>
<td>With Tin. Brittle, gray lamellated; less fusible than tin.</td>
<td>A gritty white alloy.</td>
<td></td>
<td>Mercury dissolves a large quantity of bismuth without losing its fluidity; but drops of the alloy elongate, and form a tail.</td>
</tr>
<tr>
<td></td>
<td>DUCTILE METALS.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IRON.</strong></td>
<td><strong>GOLD.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Zinc. See Galvanized Iron.</td>
<td>A greenish-yellow alloy, which will take a fine polish.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Iron or Steel</td>
<td>Gold and iron alloy with ease, and form yellowish alloys, varying in color with the proportions of the metals. Three or four parts of iron united with one of gold is very hard, and is used in the manufacture of cutting instruments.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Gold</td>
<td>Copper and gold alloy in all proportions, the copper giving hardness to the gold. This alloy is much used in coin and in the metal employed in the manufacture of jewellery.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Copper</td>
<td>Do not appear to form a true alloy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Lead, does not appear to form any alloy.</td>
<td>Of great importance. See Bronze.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Tin. A very little iron diminishes the malleability of tin, and gives it hardness.</td>
<td>The alloys of gold and tin are brittle; they preserve, however, some ductility when the proportion of tin does not exceed ( \frac{1}{13} ).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Mercury. Mercury has no action on iron.</td>
<td>Mercury has a most powerful action on gold. See Amalgam.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **COPPER.**             | **SILVER.**                                                                     |
| Iron and copper do not form true alloys. When fused together, the iron, however, retains a little copper. Several methods for coating iron with copper and brass will be described. | Gold and silver mix easily together; but they do not appear to form a true combination. Jewellers often employ for very, which is composed of 70 parts of gold and 30 of silver, which corresponds very nearly to the alloy possessing the maximum hardness. |
|                         | Silver and copper alloy in all proportions. These alloys are much used in the arts. The maximum hardness appears to be produced when the alloy contains a fifth of copper. Unite in all proportions; but a very small quantity of lead will greatly diminish the ductility of silver. |
|                         | Alloys readily. A very small quantity of tin destroys the ductility of silver. |
|                         | The amalgamation of these two metals is a little less energetic than between mercury and gold. See Amalgamation. |
ALLOY.

In addition to these, the alloys of iron appear of sufficient importance to require some further notice.

Iron and Manganese.—Mr. Musset concludes, from his experiments, that the maximum combination of manganese and iron is 40 of the former to 100 of the latter. The alloy 71:4 of tin and 28:6 of manganese is indifferent to the magnet.

Iron and Silver; Steel and Silver.—Various experiments have been made upon alloys of iron and steel with other metals. The only alloys to which sufficient importance has been given are those of iron and silver and steel and silver. M. Guyton states, in the "Annales de Chimie," that he found iron to alloy with silver in greater quantity than the silver with the iron. "Iron can," he says, "therefore no longer be said to refuse to mix with silver; it must, on the contrary, be acknowledged that these two metals, brought into perfect fusion, contract an actual chemical union; that whilst cooling, the heaviest metal separates for the greatest part; that, notwithstanding each of the two metals retains a portion of the other, as is the case in every liquidation, the part that remains is not simply mixed or interlaid, but chemically united; lastly, the alloy in these proportions possesses peculiar properties, particularly a degree of hardness that may render it extremely useful for various purposes."

The experiments of Faraday and Stodart on the alloys of iron and steel are of great value; the most interesting being the alloy with silver. The words of these experimenters are quoted:

"In making the silver alloys, the proportion first tried was 1 silver to 100 steel; the resulting buttons were uniformly steel and silver in fibres, the silver being likewise given out in globules during solidifying, and adhering to the surface of the fused buttons; some of these, when forged, gave out more globules of silver. In this state of mechanical mixture the little bars, when exposed to a damp atmosphere, evidently produced voltaic action; and to this we are disposed to attribute the rapid destruction of the metal by oxidation, no such destructive action taking place when the two metals are chemically combined. These results indicated the necessity of diminishing the quantity of silver, and 1 silver to 200 steel was tried. Here, again, were fibres and globules in abundance; with 1 to 500 the fibres diminished, but still were present; they were detected even when 1 to 400 was used. The specimen forged remarkably well, although very hard; it had in every respect the most favorable appearance. By a delicate test every part of the bar gave silver. This alloy is decidedly superior to the very best steel; and this excellence is unquestionably owing to a combination with a minute quantity of silver. It has been repeatedly made, and always with equal success. Various cutting tools have been made from it of the best quality. This alloy is, perhaps, only inferior to that of steel and rhodium, and it may be procured at small expense; the value of silver, where the proportion is so small, is not worth naming; it will probably be applied to many important purposes in the arts."

Messrs. Faraday and Stodart show from their researches that not only silver, but platinum, rhodium, gold, nickel, copper, and even tin, have an affinity for steel sufficiently strong to make them combine chemically.

Iron and Nickel unite in all proportions, producing soft and tenacious alloys. Some few years since, Mr. Nasmyth drew attention to the combination of silicon with steel. Fresh interest has been excited in this direction by the investigations of a French chemist, M. St. Claire Deville, who has examined many of the alloys of silicon.

Silicon and Iron combine to form an alloy which is a sort of fusible steel in which carbon is replaced by silicon. The silicurates are all of them quite homogeneous, and are not capable of being separated by liquidation.

Copper and Silicon unite in various proportions, according to the same chemist. A very hard, brittle, and white alloy, containing 12 per cent. of silicon, is obtained by melting together three parts silico-flouride of potassium, one part sodium, and one part copper, at such a temperature that the fused mass remains covered with a very liquid scoria. The copper takes up the whole of the silicon, and remains as a white substance less fusible than silicon, which may serve as a base for other alloys. An alloy with 5 per cent. silicon has a beautiful bronze color, and will probably receive important applications.

Mr. Oxland and Mr. Truran have given, in "Metals and their Alloys," the following useful tabular view of the composition of the alloys of copper.

The principal alloys of copper with other metals are as follows:
<table>
<thead>
<tr>
<th>Copper</th>
<th>Zinc</th>
<th>Tin</th>
<th>Nickel</th>
<th>Antimony</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>87-000</td>
<td>-</td>
<td>-</td>
<td>13-000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>97-000</td>
<td>-</td>
<td>-</td>
<td>3-000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>91-400</td>
<td>5-300</td>
<td>1-700</td>
<td>-</td>
<td>-</td>
<td>1-370</td>
</tr>
<tr>
<td>90-000</td>
<td>-</td>
<td>-</td>
<td>10-000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>90-000</td>
<td>-</td>
<td>-</td>
<td>10-000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>78-000</td>
<td>-</td>
<td>-</td>
<td>22-000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>82-257</td>
<td>17-481</td>
<td>0-258</td>
<td>-</td>
<td>-</td>
<td>0-024</td>
</tr>
<tr>
<td>80-000</td>
<td>16-500</td>
<td>2-500</td>
<td>-</td>
<td>-</td>
<td>1-000</td>
</tr>
<tr>
<td>68-000</td>
<td>-</td>
<td>33-000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>84-700</td>
<td>15-200</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0-28</td>
</tr>
<tr>
<td>73-700</td>
<td>27-270</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>80-200</td>
<td>-</td>
<td>20-000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>75-000</td>
<td>25-000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>50-000</td>
<td>-</td>
<td>50-000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>70-220</td>
<td>29-260</td>
<td>0-17</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>56-000</td>
<td>35-000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10-000</td>
<td>3-000</td>
<td>67-000</td>
<td>0-03</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>60-000</td>
<td>40-000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>80-000</td>
<td>9-200</td>
<td>60-000</td>
<td>8-3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>80-000</td>
<td>9-200</td>
<td>30-000</td>
<td>2-00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1-000</td>
<td>2-00</td>
<td>82-000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>16-000</td>
<td>-</td>
<td>-</td>
<td>10-000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>80-000</td>
<td>17-8</td>
<td>-</td>
<td>-</td>
<td>22-2</td>
<td>-</td>
</tr>
<tr>
<td>50-000</td>
<td>13-6</td>
<td>-</td>
<td>19-8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>50-000</td>
<td>25-0</td>
<td>-</td>
<td>23-0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**ALLOY, NATIVE. OSMIUM and IRIDIUM.** In the proportions of 72-9 of the former and 24-5 of the latter. See Osmium, Iridium.

**ALLSPICE.** Pimento, or Jamaica pepper, so called because its flavor is thought to be similar to that of a mixture of cinnamon, cloves, and nutmegs. It is grown in Jamaica, where it is called Pimento walks. It is imports into Europe, almost entirely from Jamaica.

**ALMOND. (Amande, Fr.; Mandeln, Germ.; Amygdal communis.)** De Candolle admits five varieties of this species. *A. amara*, bitter almond; *A. dulcis*, sweet almond; *A. fragilis*, tender-shelled almond; *A. macrocarpa*, large-fruited almond; *A. persicoides*, peach almond.

Three varieties are known in commerce:

1. *Jordan Almonds*, which are the finest, come from Malaga. Of these there are two kinds: the one above an inch in length, flat, with a clear brown cuticle, sweet, mucilaginous, and rather tough; the other more plump and pointed at one end, brittle, but equally sweet with the former.

2. *Valencia Almonds* are about three-eighths of an inch broad, not quite an inch long, round at one end, and obtusely pointed at the other, flat, of a dingy brown color, and dusty cuticle.

3. *Barbary and Italian almonds* resemble the latter, but are generally smaller and less flattened. — *Braude, Dictionary of Pharmacy.*

**ALMOND OIL.** A bland fixed oil, obtained by expression from either bitter or sweet almonds; usually from the former, on account of their cheapness as well as the greater value of the residual cake. The average product is from 48 to 52 lbs. from 1 cwt. of almonds. — *Pereira.*

**ALMOND POWDER** (*farina amygdalae*) is the ground almond cake, and is employed as a cake for washing the hands, and as a lute.

**ALOE. (Aloe, Fr.; Gloxinia aloe, Germ.)** In botany a genus of the class *Hederaeina monocephala.* There are many species, all natives of warm climates. In Africa the leaves of the Guinca aloe are made into durable ropes. Of one species are made lines, bow-strings, stockings, and hammocks; the leaves of another species are used to hold rain water.

A patent has been taken (January 27th, 1847) for certain applications of aloes to dyeing. Although it has not been employed, the coloring matter so obtained promising to be very permanent and intense, it is thought advisable to describe the process by which it is proposed to prepare the dye. It is as follows:

Into a boiler or vessel capable of holding about 100 gallons, the patentee puts 10 gallons of water, and 132 lbs. of aloes, and heats the same until the aloes are dissolved; he then adds 80 lbs. of nitric or nitrous acid in small proportions at a time, to prevent the discoul...
gagement of such a quantity of nitrous gas as would throw part of the contents out of the boiler. When the whole of the acid has been introduced, and the disengagement of gas has ceased, 10 lbs. of liquid caustic soda, or potash of commerce, of about 30⁰, are added to neutralize any undecomposed acid remaining in the mixture, and to facilitate the use of the mixture in dyeing and printing. If the coloring matter is required to be in a dry state, the mixture may be coagulated with 100 lbs. of clarified and dried in stones, or by means of a current of air. The coloring matter is used in dyeing by dissolving a sufficient quantity of water, according to the shade required, and adding as much hydrochloric acid or tartar of commerce as will neutralize the alkali contained in the mixture, and leave the dye bath slightly acidulated. The articles to be dyed are introduced into the bath, which is kept boiling until the desired shade is obtained.

When the coloring matter is to be used in printing, a sufficient quantity is to be dissolved in water, according to the shade required to be produced; this solution is to be thickened with gum, or other common thickening agent, and hydrochloric acid, or tartar of commerce, or any other suitable supersalt, is to be added thereto. After the fabrics have been printed with the coloring matter, they should be subjected to the ordinary process of steaming, to fix the color.—Napier.

Alloetic acid, on which the coloring matter of the aloe depends, has been examined by Schuch and Mulder. Alloetic acid is deposited, from nitric acid which has been heated with aloe, as a yellow powder; it dissolves in ammonia with a violet color; when treated with protochloride of tin, it forms a dark-violet heavy powder; and this, again, when treated with potash, evolves ammonia, and assumes a violet-blue color. The solution of alloetic acid in ammonia is violet.

ALPACA. (Alpaca, Fr.) An animal of Peru, of the Llama species; also the name given to a woollen fabric woven from the wool of this animal.

ALUM. (Alum, Fr.; Alun, Germ.) A saline body or salt, consisting of alumina, or the peculiar earth of clay, united with sulphuric acid, and these again united with sulphate of potash or ammonia. In other words, it is a double salt, consisting of sulphate of alumina and sulphate of potash, or sulphate of alumina and sulphate of ammonia. The common alum crystallizes in octahedrons, but there is a kind which takes the form of cubes. It has a sour or rather subacid taste, and is peculiarly astringent. It reddens the blue color of litmus or red cabbage, and acts like an acid on many substances. Other alkalies may take the place of the ammonia or potash, or other metals that of the aluminium.

The composition of alum is expressed by chemists in the following manner: \( \text{Al}_2\text{O}_3 \cdot 3\text{SO}_3 \cdot \text{K}_2\text{O} \cdot 2\text{H}_2\text{O} \). This peculiar combination is that of the original substance as far as it appeared to the chemists of last century, and the form is now held as a type, after which many other alums are composed. Ammonia-alum was occasionally made, even as early as Agricola's time, 16th century. Its composition is \( \text{Al}_2\text{O}_3 \cdot 3\text{SO}_3 \cdot \text{NH}_4 \cdot \text{H}_2\text{O} \cdot 2\text{H}_2\text{O} \). The same thing occurs with soda; soda alum is \( \text{Al}_2\text{O}_3 \cdot 3\text{SO}_3 \cdot \text{Na}_2\text{O} \cdot 2\text{H}_2\text{O} \). Every salt having this form is called an alum. Sometimes, instead of the alkali being changed, the earth is changed. Thus we have: chrome-alum, \( \text{Cr}_2\text{O}_3 \cdot 3\text{SO}_3 \cdot \text{K}_2\text{O} \cdot 2\text{H}_2\text{O} \); or we have an iron-alum, \( \text{Fe}_2\text{O}_3 \cdot 3\text{SO}_3 \cdot \text{K}_2\text{O} \cdot 2\text{H}_2\text{O} \). These may be varied to a great extent, but all have a characteristic of alum. The twenty-four atoms of water are one of the peculiar characteristics.

Composition of pure Potash Alum.

<table>
<thead>
<tr>
<th>Per Cent.</th>
<th></th>
<th>Per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potash</td>
<td>9-39 or 1 atom 47</td>
<td>Sulphate of potash 18-82 or 1 atom 27</td>
</tr>
<tr>
<td>Alumina</td>
<td>10-94 1 1 1 52</td>
<td>Sulphate of alumina 36-21 1 1 172</td>
</tr>
<tr>
<td>Sulphuric acid 33-68 1 4 1 100</td>
<td>Water 45-48 1 1 218</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>45-49 24 210</td>
<td>Its specific gravity is 1-724.</td>
</tr>
</tbody>
</table>

100 parts of water dissolve, at 32 degrees Fahrenheit, 3-29 alum.

These Tables of Poggiale should be re-examined, and gradations made more useful for this country.

Solubility.—1 part of crystallized potash alum is soluble—

At 54 degrees Fahrenheit in 13:5 water.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70</td>
<td>8-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>77</td>
<td>4-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>2-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>122</td>
<td>2-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>145</td>
<td>9-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>167</td>
<td>0-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>189-3</td>
<td>9-96</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ALUM.

A solution saturated at 46° is 1·045 specific gravity. This difference in the rate of solubility in hot and cold water renders it easily separated from many other salts. The crystals are permanent in the air, or nearly so, unless the air be very dry; if kept at 180° they lose 15 atoms of water, but alum deprived of its water and exposed to the air of summer took up 18 atoms in 47 days. It melts at a low temperature in its water of crystallization. At 35° it loses 43·5 per cent. of water, or 22 atoms; the last atom is only lost when approaching red heat. At a red heat the sulphate of alumina loses its acid, and the alumina seems then able to remove some acid from the potash, losing it again by heat. Alum, when heated with common salt, acts like sulphuric acid, and gives off muriatic acid; the same with chlorides of potassium and ammonium. If boiled with a saturated solution of chloride of potassium, hydrochloric acid is formed and a sub sulphate of alumina falls down; this occurs only to a small extent with chloride of sodium, and still less with sal-ammoniac.

Applications of Alum.—Alum is an astringent. Its immediate effect on man is to corrogate the fibres and contract the small vessels. It precipitates albuminous liquids and combines with gelatine. It causes dryness of the mouth and throat, and checks the secretions of the alimentary canal, producing constipation; in large quantities, nausea, vomiting, purging. It is given in lead colic, to convert the lead into sulphate of lead, and used externally. Its principal use is in dyeing; calico-printers print it as a mordant, the cloth is then put into the dye, and the printed parts absorb the color. Paper-makers use it in their size and bookbinders in their paste. It is used in tanning leather, and sometimes, both in Asia and Europe, it is used for precipitating rapidly the impurities of water. This is a dangerous process, unless there be a great amount of alkaline salts, such as carbonate of lime or soda to neutralize the acid. It is extensively used in correcting the baking qualities of bad flour, for which the experience of many has decided that it is a valuable remedy; unfortunately, it is also used to make excellent flour whiter, when there is no need of its presence. Liebig says that lime is equally good, and of course much safer. From time immemorial it has been used to prevent the combustibility of wood and cloth.

Alum heated with charcoal or carbonaceous substances forms Homberg's phosphorus, which inflames spontaneously. It is composed of alumina, sulphide of potassium, and charcoal.

Burnt Alum, or dried alum, is made by gently heating alum till the water is driven off. The alum first melts in its water of crystallization and is then dried. It has a stronger action than the hydrated crystals, and is a mild escharotic. It redabsorbs water.

Ammonia-alum readily loses all its ammonia when heated, and the sulphuric acid may be driven off the remaining sulphate of alumina, so that the pure earth-alumina will remain.

Neutral Alum is a name sometimes given erroneously to alum which has had some of its acid neutralized by an alkali. It is, in fact, a basic salt of alumina, which may also be made by dissolving alumina in ordinary alum. It deposits a basic salt more readily than ordinary alum, and may be of service in some cases of printing. Properly speaking, the common alum is the neutral salt.

Testing of Alum.—Alum being generally in large crystals, any impurity is more readily seen; this is said to be the reason for keeping up the practice of making this substance instead of the sulphate of alumina alone, which is less bulky and fitted for nearly every purpose for which alum is used. But probably the ancient accidental discovery of the potash form has determined its use to the present day. Iron is readily found in it, by adding to a dilute solution ferrocyanide of potassium or prussiate of potash, which throws down Prussian blue. A very delicate test is sulphuret of ammonium, which throws down both the alumina and iron, but the blacking of the precipitate depends on the amount of iron. The total amount of iron is got by adding pure caustic potash or soda till the solution is strongly alkaline, washing and filtering off the oxide. To look for lime, precipitate the alumina and iron by ammonia, boil and filter, the lime and magnesium are in the solution, add oxalate of ammonia; add tartaric acid to keep up the iron and alumina, make alkaline by ammonia, then precipitate the lime by oxalate of ammonium, filter, and precipitate the magnesia by a phosphate. Silica and insoluble basic sulphates are obtained by simply dissolving the alum in water and filtering. If silica, it is insoluble in acids; if a basic sulphate, it will dissolve in sulphuric acid, and the addition of sulphate of potash or ammonium will convert it into potash or ammonium-alum.

Its formula, according to Graham, is a basic alum, \( \text{H}_2\text{SO}_4 \cdot 3(\text{AlF}_3\text{SO}_7) \cdot 9\text{H}_2\text{O} \).

By losing alumina it becomes the neutral salt.

Sulphate of Alumina.—The first step towards the production of alum is the sulphate of alumina. This is found in various proportions in alum stone. The pure mineral has the following composition :

| 1 atom of alumina | - | 15·42 per cent. |
| 3 atoms of sulphuric acid | - | 55·09 " |
| 18 atoms of water | - | 48·59 " |

100
ALUM.

There are many analyses of natural specimens closely approaching this. It is found crystallized in a close mass of fine, white, flexible needles, of a feather or hair form, and has been, like a few other substances, called hair-salt. It is also found with various degrees of impurity, sometimes with a smaller amount of water. Knapp has collected the following list of analyses:

**Analyses of Natural Sulphate of Alumina or Feather Alum.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sulphuric Acid</th>
<th>Alumina</th>
<th>Peroxide of Iron</th>
<th>Protic acid</th>
<th>Protic acid of Iron</th>
<th>Protic acid mangan.</th>
<th>Potash</th>
<th>Soda</th>
<th>Lime</th>
<th>Magnesia</th>
<th>Marltic acid</th>
<th>Silica</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salfutara</td>
<td>14.98</td>
<td>10.00</td>
<td>15.0</td>
<td>14.03</td>
<td>12</td>
<td>2.68</td>
<td>2.48</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>1.32</td>
<td>48.94</td>
</tr>
<tr>
<td>Salfutara</td>
<td>14.98</td>
<td>10.00</td>
<td>15.0</td>
<td>14.03</td>
<td>12</td>
<td>2.68</td>
<td>2.48</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>1.32</td>
<td>48.94</td>
</tr>
<tr>
<td>Salfutara</td>
<td>14.98</td>
<td>10.00</td>
<td>15.0</td>
<td>14.03</td>
<td>12</td>
<td>2.68</td>
<td>2.48</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>1.32</td>
<td>48.94</td>
</tr>
<tr>
<td>Salfutara</td>
<td>14.98</td>
<td>10.00</td>
<td>15.0</td>
<td>14.03</td>
<td>12</td>
<td>2.68</td>
<td>2.48</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>1.32</td>
<td>48.94</td>
</tr>
</tbody>
</table>

The manufacture of alum involves the making of sulfates of alumina in the first instance in all cases where potash is not present in the ore; for this reason the description of both is included in one article.

**Ores or Raw Material.**—The chief difficulty in manufacturing alum has been the solution of the alumina. This substance is generally combined with silica in such a strong combination, that even powerful acids cannot remove it without assistance. The older methods, however, took no notice of these difficulties, and obtained the alum more or less directly from nature. The method now practised at the Solfatara di Pozzolani and the island Vulcano is simply to take the efflorescence and the earth containing it, wash it with water, and concentrate. But it very seldom contains a sufficient amount of potash to form alum. A salt of potash is then added, chiefly a carbonate. To transform this into a sulphate, a portion of the sulphate of alumina is decomposed. The use of a carbonate is a wasteful method of modern times; the ancients would have felt no difficulty, but boiled all down, and so obtained the whole alumina there. Their product, therefore, would have been basic sulphate of alumina, which it evidently was when this practice was resorted to. When they merely concentrated and then crystallized, they got pure alum; but they lost a great deal of their alumina.

At Tolla the alum is obtained from a compact crystalline substance called alunite. The analysis of Cordier makes it a combination of alum with alunite. If treated with water only, it will not give out alum; but if moderately calcined, it breaks up, gives out a large amount of alum, and the liquid is then boiled down for crystallization.

Here are specimens of the ore, two of which contain a considerable amount of potash. As there is seldom enough of potash found, it must be added in the form of sulphate of potash or chloride of potassium.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sulphuric Acid</th>
<th>Alumina</th>
<th>Potash</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salfutara</td>
<td>14.98</td>
<td>10.00</td>
<td>15.0</td>
<td>18.124</td>
</tr>
<tr>
<td>Salfutara</td>
<td>14.98</td>
<td>10.00</td>
<td>15.0</td>
<td>18.124</td>
</tr>
<tr>
<td>Salfutara</td>
<td>14.98</td>
<td>10.00</td>
<td>15.0</td>
<td>18.124</td>
</tr>
<tr>
<td>Salfutara</td>
<td>14.98</td>
<td>10.00</td>
<td>15.0</td>
<td>18.124</td>
</tr>
</tbody>
</table>

These formations of alum are generally found where sulphurous gases are exhaled: the rock is gradually decomposed.
ALUM

It is not, however, found so rich in the great majority of cases. The following are analyses of some alum stones:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tolfa</td>
<td>Beregarz</td>
<td>Montane.</td>
<td>Mont d'Or.</td>
</tr>
<tr>
<td>Silica</td>
<td>56·5</td>
<td>62·3</td>
<td>-</td>
<td>28·4</td>
</tr>
<tr>
<td>Alumina</td>
<td>19·0</td>
<td>17·5</td>
<td>40·0</td>
<td>31·8</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>16·3</td>
<td>12·5</td>
<td>55·6</td>
<td>27·0</td>
</tr>
<tr>
<td>Potash</td>
<td>4·9</td>
<td>1·0</td>
<td>13·8</td>
<td>5·8</td>
</tr>
<tr>
<td>Water</td>
<td>5·0</td>
<td>5·9</td>
<td>10·0</td>
<td>3·7</td>
</tr>
<tr>
<td>Oxide of iron</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1·4</td>
</tr>
</tbody>
</table>

When there is no silica, but only sulphuric acid, alumina, and potash, we have a natural alum, and in that case there is nothing to be done towards the manufacture. But it rarely happens that the constituents exist in a proportion to form the crystalline salt. There may be sulphate of alumina, hydrate of alumina, and some true alum, or sulphate of alumina and potash. This excess of hydrate of alumina forms, when united with the sulphate, a basic or insoluble sulphate of alumina, and nothing but the sulphate of potash becomes soluble. When the hydrate is heated, the water escapes; the sulphate of alumina and potash are then capable of being washed out together, and alum is obtained. At Tolfa it is obtained in crystals, covered over with a light red powder of peroxide of iron. This reddish covering always accompanies the Roman or partly cubical alum, and it has been sometimes added in order to give common alum the appearance of the Roman.

As the principal difficulty in the manufacture of alum is the solution of the alumina, it is unfortunate that so much of the hydrate is destroyed, as in the process mentioned, when sulphuric acid would readily dissolve it and greatly increase the produce. By the method described to us, the measure of alum is simply the amount of the potash. All that cannot find potash to unite with is lost.

Occasionally ammonia-alum is found in nature. Analyses have been made of specimens from Tschermig, in Bohemia, by Stromeyer:

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alumina</td>
<td>Ammonia</td>
<td>Magnesia</td>
<td>Sulphuric acid</td>
</tr>
<tr>
<td></td>
<td>11·982</td>
<td>3·721</td>
<td>0·118</td>
<td>36·065</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Soda-alum is also found naturally.

Alum from Peru, by T. Thomson.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sulphate of soda</td>
<td>Alumina</td>
<td>Sulphuric acid</td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>6·50</td>
<td>22·35</td>
<td>32·95</td>
<td>39·20</td>
</tr>
<tr>
<td></td>
<td>101·20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the Andes.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sulphuric acid</td>
<td>Alumina</td>
<td>Soda</td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>36·199</td>
<td>11·311</td>
<td>7·259</td>
<td>43·819</td>
</tr>
<tr>
<td></td>
<td>100·162</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Messrs. Richardson and Ronalds have given some very minute analyses of the Whitby and Campsie shales.
As the Top one contains a larger excess of iron pyrites than the Bottom, they are mixed so as to diffuse the sulphuric acid equally.

Erdmann has thus analyzed his German specimens:

<table>
<thead>
<tr>
<th>Soluble in acid</th>
<th>Whitby</th>
<th>Campsie</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top Rock</td>
<td>Bottom Rock</td>
</tr>
<tr>
<td>Sulphuret of iron</td>
<td>4:20</td>
<td>8:50</td>
</tr>
<tr>
<td>Silica</td>
<td>52:25</td>
<td>51:16</td>
</tr>
<tr>
<td>Protioxide of iron</td>
<td>8:49</td>
<td>8:11</td>
</tr>
<tr>
<td>Alumina</td>
<td>18:75</td>
<td>18:30</td>
</tr>
<tr>
<td>Lime</td>
<td>1:25</td>
<td>2:15</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0:01</td>
<td>0:90</td>
</tr>
<tr>
<td>Oxide of manganese</td>
<td>traces</td>
<td>traces</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>1:37</td>
<td>2:50</td>
</tr>
<tr>
<td>Potash</td>
<td>0:13</td>
<td>traces</td>
</tr>
<tr>
<td>Soda</td>
<td>0:20</td>
<td>traces</td>
</tr>
<tr>
<td>Chlorine</td>
<td>traces</td>
<td>traces</td>
</tr>
<tr>
<td>Carbon and loss</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carbon</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coal</td>
<td>4:97</td>
<td>8:29</td>
</tr>
<tr>
<td>Loss</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Water</td>
<td>2:88</td>
<td>2:00</td>
</tr>
</tbody>
</table>

Other shales will be found of interest; the following are by G. Kersten:

<table>
<thead>
<tr>
<th>Insoluble in acid</th>
<th>Herman-schachte</th>
<th>Glückauf-gang</th>
<th>Blücher-schachte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur</td>
<td>-</td>
<td>-</td>
<td>41:10</td>
</tr>
<tr>
<td>Silica</td>
<td>-</td>
<td>-</td>
<td>44:02</td>
</tr>
<tr>
<td>Peroxide of iron</td>
<td>-</td>
<td>-</td>
<td>6:28</td>
</tr>
<tr>
<td>Alumina</td>
<td>-</td>
<td>-</td>
<td>5:60</td>
</tr>
<tr>
<td>Magnesia</td>
<td>-</td>
<td>-</td>
<td>0:32</td>
</tr>
<tr>
<td>Water</td>
<td>-</td>
<td>-</td>
<td>1:25</td>
</tr>
<tr>
<td>Carbonaceous matter</td>
<td>-</td>
<td>-</td>
<td>1:02</td>
</tr>
<tr>
<td>Coal</td>
<td>-</td>
<td>-</td>
<td>22:83</td>
</tr>
<tr>
<td>Water</td>
<td>-</td>
<td>-</td>
<td>2:208</td>
</tr>
</tbody>
</table>
### ALUM

<table>
<thead>
<tr>
<th>Alumina</th>
<th>Silica</th>
<th>Magnesia</th>
<th>Sulphur</th>
<th>Carbon</th>
<th>Proximate of iron</th>
<th>Oxide of manganese</th>
<th>Sulphate of protoxide of iron</th>
<th>lime</th>
<th>potash</th>
<th>Chloride of potassium</th>
<th>Sulphuric acid</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.00</td>
<td>40.00</td>
<td>6.40</td>
<td>2.83</td>
<td>19.65</td>
<td>6.40</td>
<td>0.40</td>
<td>1.80</td>
<td>1.50</td>
<td>1.50</td>
<td>0.50</td>
<td>0.47</td>
<td>10.75</td>
</tr>
</tbody>
</table>

Here the sulphur has evidently existed in combination with iron, which has been united to oxygen by the analysts. The amount of sulphate shows a partial disintegration and other changes.

Lampadius gives another with much more sulphur:

#### Alum Shale from Siehda

<table>
<thead>
<tr>
<th>Sulphate of alumina</th>
<th>Potash-lime</th>
<th>Sulphate of iron</th>
<th>Alumina</th>
<th>Magnesia</th>
<th>Oxide of iron</th>
<th>Oxide of manganese</th>
<th>Sulphur</th>
<th>Water</th>
<th>Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.68</td>
<td>0.47</td>
<td>0.95</td>
<td>1.70</td>
<td>10.32</td>
<td>9.21</td>
<td>2.30</td>
<td>7.13</td>
<td>33.90</td>
<td>61.68</td>
</tr>
</tbody>
</table>

When alum is made of such shale, the object is first of all to oxidize the sulphur, forming sulphuric acid. This acid then dissolves the alumina. The result may be accomplished by allowing the shale to disintegrate spontaneously in the air, the sulphur oxidizing and dissolving the alumina. But in general, as at Whithby and Campsie, combustion must be resorted to. This can be accomplished without the use of coal, further than is needful simply to set fire to that portion which exists in the shale itself. Indeed, the Campsie one, having more coal than is desirable for slow combustion, is mixed with some spent material, in order to diminish the force of the heat.

The sulphur is united with the iron, forming a bisulphuret, each atom of which must therefore take up seven atoms of oxygen, FeS₂+7O=FeO Sₐ+SO₂. When combustion takes place, the sulphur oxidizes; if rapid combustion is used, then sulphurous acid gas escapes; if slow combustion, the sulphurous acid penetrates the mass slowly, receives another atom of oxygen, unites to a base, and a sulphate is the consequence. Sulphate of iron is formed and pure sulphuric acid. In the process it is probable that the oxidation is completed by means of the iron. Protoxide of iron readily becomes peroxide; the sulphurous acid readily decomposes peroxide, forming sulphuric acid and protoxide of iron. This protoxide of iron is again converted into peroxide, and if not dissolved is rendered, to a great extent, difficult to dissolve, by reason of the heat of the mass. For this reason, partly, there is less sulphate of iron in the alum than might be expected. To effect these changes it is desirable to burn very slowly, so as to allow no loss of sulphuric acid, and, in washing, to allow the water to stand a long time on the burnt ore. Another method, by which the sulphuric acid is transferred to the alumina, is the peroxidation of the protoxide in the sulphate of iron; acid is by this means set free and begins to act on the alumina.

The protosulphate of iron being formed, it is removed by boiling down the liquor until the protosulphate of iron crystallizes out, at the same time the solution becoming saturated with the aluminous salt. The sulphate of iron is soluble in 0.3 of hot water, the alum in 0.06. The liquid around the crystals on the remaining mother liquor contains iron also; this is washed off by adding pure liquors.
ALUM.

The presence of lime or magnesia in the ores is, of course, a means of abstracting acid, preventing the alumina being dissolved, and even precipitating it when dissolved.

Knapp says that at Salzweller, near Duttenweiler, in Rhenish Prussia, the roasting of the ore takes place in the pit or mine. The stratum of brown coal which lies under it, having been accidentally set fire to in 1660, has smouldered till the present time without intermission.

When the ores are roasted, one-half of the sulphur is freed and sent into the mass or escapes as sulphurous acid; and the remaining, protosulphuret of iron, is afterwards converted into green vitriol.

After calcining and washing the Campsie ores, the residue had the following composition:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>38.40</td>
</tr>
<tr>
<td>Alumina</td>
<td>12.70</td>
</tr>
<tr>
<td>Peroxide of iron</td>
<td>20.80</td>
</tr>
<tr>
<td>Oxide of manganese</td>
<td>traces</td>
</tr>
<tr>
<td>Lime</td>
<td>2.07</td>
</tr>
<tr>
<td>Magnesia</td>
<td>2.90</td>
</tr>
<tr>
<td>Potash</td>
<td>1.00</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>10.75</td>
</tr>
<tr>
<td>Water</td>
<td>12.27</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.00</td>
</tr>
</tbody>
</table>

It is, therefore, very far from being a complete process; but it is not considered profitable to remove the whole of the alumina. In some places the exhausted ore is burnt a second time with fresh ore, as at Campsie, but we are not told the estimated exhaustion.

In preparing alum from clay or shale, it is of infinite importance that so much and no more heat be applied to the clay or shale, in the first instance, as will expel the water of combination without inducing contraction. A temperature of 600° F. is well adapted to effect this object, provided it be maintained for a sufficient period. When this has been carefully done, the silicate of alumina remaining is easily enough acted upon by sulphuric acid, either slightly diluted or of the ordinary commercial strength. The best form of apparatus is a leaden boiler, divided into two parts by a perforated septum or partition, also in lead; though on a very large scale, brickwork set in clay might be employed. Into one of the compartments the roasted clay or shale should be put, and diluted sulphuric acid being added, the bottom of the other compartment may be exposed to the action of a well-regulated fire, or, what is better, heated by means of steam through the agency of a coil of leaden pipe. In this way a circulation of the fluid takes place throughout the mass of shale; and, as the alumina dissolves, the dense fluid it produces, falling continually to the bottom of the boiler, is replaced by dilute acid, which, becoming in its turn saturated, falls like the first; and so on in succession, until either the whole of the alumina is taken up, or the acid in great part neutralized. The solution of sulphate of alumina thus obtained is sometimes evaporated to dryness, and sold under the name “concentrated alum”; but more generally it is boiled down until of the specific gravity of about 1.35; then one or other of the carbonates or sulphates of potash or ammonia, or chloride of either base, or a mixture of these, is added to the boiling fluid, and as soon as the solution is complete, the whole is run out into a cooler to crystallize. The rough alum thus made is sometimes purified by a subsequent recrystallization, after which it is “roched” for the market—a process intended merely to give it the ordinary commercial aspect, but of no real value in a chemical point of view.

The manufacture of alum is now taking an entirely new shape, and the two processes of Mr. Spence and Mr. Pochin threaten to absorb the whole of the manufacture in the northwest.

Mr. Spence, who has a manufactory of ammonia-alum at Manchester, called the Pendleton Alum Works, and another at Goole, in Yorkshire, has now become the largest maker of this substance in the world, as his regular production amounts to upwards of 100 tons per week. In this process, which he has patented, he uses for the production of his sulphate of alumina solution the carbonaceous shale of the coal measure. This substance contains from 5 to 10 per cent. of carbonaceous matter, and, when ignited by a small quantity of burning coal, the combustion continues of itself. To insure this the shale is spread into long heaps not exceeding 18 inches in height, and having a brick drain running along each to supply air; in this manner it slowly calcines; this process must be so conducted as not to vitrify the shale. After calcination it is boiled and digested in large leaden pans, heated by fire, with sulphuric acid of 1° specific gravity. After 20 to 40 hours of digestion the sulphate of alumina formed is run into another leaden pan, and the boiling vapor from the ammonia liquor of the gas works is passed into it, until so much alumina is combined with the solution as to form ammonia-alum. The solution is then run into shallow leaden cool-
ALUMINA, ACETATE OF.

ers, and the alum crystallizes. It is then purified and washed much in the usual way, only that the process is conducted so as to cause much less labor than at other alum works.

Alum Cake.—This substance owes its value to the amount of sulphate of alumina it contains, and is in fact another means of making soluble alumina accessible. We have already seen the many attempts to obtain alumina from clay, and the tedious nature of the operation of solution in acid, as well as the long after-processes of lixiviation and conversion into sulphate of alumina, or into alum, by reboiling or crystallizing. Mr. Pochin, of Manchester, has found a method of removing all the difficulties, both of the first and after-processes. He uses very fine China clay, free from iron, heats it in a furnace, mixes it thoroughly with acid, and finds that, when the process is managed carefully, the combination of the alumina and sulphuric acid is not only complete, but so violent that he is obliged to dilute his acid considerably, in order to calm the action. When mixed, it is passed into cisterns with movable sides, where, in a few minutes, it heats violently and boils. The thick liquid gradually becomes thicker, until it is converted into a solid porous mass—the pores being made by the bubbles of steam which rise in the mass, which is not fluid enough to contract to its original volume. The porous mass is perfectly dry, although retaining a large amount of combined water. It retains, of course, all the silicea of the original clay, but this is in such fine division that every particle appears homogeneous. The silicea gives it a dryness to the touch not easily gained by the sulphate only.

When pure sulphate of alumina is wanted in solution, the silicea is allowed to precipitate before using it, but, in many cases, the fine silicea is no hindrance; then the solution is made up of at once.—R. A. S.

ALUMINA. (AlPO₄, 514.) This is the only oxide which the metal aluminium forms, and it is assumed to be a sesquioxide on account of its isomorphism with sesquioxide of iron.

The occurrence of alumina in the native state has been before mentioned, and the several minerals will be found described elsewhere.

It is obtained in the state of hydrate from common alum (K₂O, SO₄; Al₂O₃. 3SO₄ + 24H₂O) by adding a solution of ammonia (or better, carbamate of ammonia) to the latter salt, and boiling. The precipitate is white, and gelatinous in a high degree, and retains the salts, in the presence of which it has been formed, with remarkable persistency, so that it is very difficult to wash.

By drying and igniting this hydrate, the anhydrous alumina is produced; but it may be obtained more readily by heating ammonia-alum, (NH₄, SO₄; Al₂O₃. 3SO₄ + 24H₂O) All the constituents of this salt are volatile, with the exception of the alumina. It is insoluble in water, but soluble both in acids and alkalies. Towards the former it plays the part of a base, producing the ordinary alumina salts; whilst, with the latter, it also enters into combination, but in this case it is an acid, forming a series of compounds which may be called aluminates.

The important application of alumina and its compounds in the arts of dyeing and calico-printing, depends upon a peculiar attraction which it possesses for organic bodies. This affinity is so strong, that when digested in solutions of vegetable coloring matters, the alumina combines with and carries down the coloring matter, removing it entirely from the solution. Pigments thus obtained, which are combinations of alumina with the vegetable coloring matters, are called "Indes." Alumina has not only an affinity for the coloring matters, but at the same time also for the vegetable fibres, cotton, silk, wool, &c.; and hence, if alumina be precipitated upon cloth in the presence of a coloring matter, a most intimate union is effected between the cloth and the color. Alumina, when employed in this way, is called a "mordant."

Other bodies have a similar attraction for coloring matters, e.g., binoxide of tin and sesquioxide of iron; each of these gives its peculiar shade to the color or combination, alumina changing it least.

Soluble Modification of Alumina—Mr. Walter Crum* has discovered a peculiar soluble modification of alumina. The bicarbonate of alumina has been found by Mr. Crum to possess the very curious property of parting with its acetic acid until the whole is expelled, by the long-continued application of heat to a solution of this salt; the alumina remains in the solution in a soluble allotropic condition. Its coagulum with dyewoods is translucent, and entirely different from the opaque cakes formed by ordinary alumina; hence this solution cannot act as a mordant. But this solution of alumina, which is perfectly colorless and transparent, has the alumina separated from it by the slightest causes. A minute quantity of either an acid, an alkali, even of a neutral salt, or of a vegetable coloring matter, effects the change. The precipitated alumina is insoluble in acids, even boiling sulphuric; this shows another allotropic condition. But it is dissolved by caustic alkalies, by which it is restored to its common state.—H. M. W.

ALUMINA, ACETATE OF. The acetates of alumina are extensively used in the arts on account of the property which they possess of being readily decomposed with deposition of their alumina on the fibre of cloth; hence they are used as mordants, in the manner de-

ALUMINA, SILICATES OF.

scribed under Calico Printing: and sometimes in dyeing they are mixed with the solution of a coloring matter; in this the textile fabric is immersed, whilst, on heating, the alumina is precipitated upon the fabric, which, in consequence of its affinity before alluded to, carries down the coloring matter with it, and fixes it on the cloth.

The acetate of alumina thus employed is obtained by treating sulphate of alumina with neutral acetate of lead, and filtering off the solution from the precipitate of sulphate of lead. Acetate of lime is also used; but the sulphate in this case does not leave the solution so clear or so rapidly.

According to Mr. Walter Crum, the solution resulting from the decomposition of sulphate of alumina (APO₄, 380°) by monobasic acetate of lead contains the salt APO₄, 2CH₃COO, (bacacetate of alumina,) together with one equivalent of free acetate acid, the compound APO₄, 2CH₃COO not appearing to exist. By evaporating this solution at low temperatures, e. g., in a very thin layer of fluid below 88° C., (100° F.) Crum obtained a fixed residue completely soluble in water, the composition of which, in the dry state, approached APO₄, 2CH₃COO + 4H₂O.—H. M. W.

ALUMINA, SILICATES OF. Silicate of alumina is the chief constituent of common clay, (which see:) it occurs also associated with the silicates of iron, magnesia, lime, and the alkalies in a great variety of minerals, which will be found described elsewhere. The most interesting of these are the feldspars and the zeolites. See Clay.

Of course, being present in clay, silicate of alumina is the essential constituent of porcelain and earthenware. See Porcelain.—H. M. W.

ALUMINA, SULPHATE OF. The neutral sulphate of alumina, APO₄, 380°+18H₂O, which is obtained by dissolving alumina in sulphuric acid, crystallizes in needles and plates; but sulphuric acid and alumina combine in other proportions, e. g., a salt of the formulas APO₄, 380°+Al₂O₃ was obtained by Mons, and the solution of this salt, when largely diluted with water, splits into the neutral sulphate and an insoluble powder containing APO₄, 380°+2Al₂O₃+9H₂O. This subsalt forms the mineral alunite, found near Newhaven, and was found by Humboldt in the schists of the Andes.

The sulphate of alumina is now extensively used in the arts instead of alum, under the name of "concentrated alum." For most of the purposes for which alum is employed, the sulphate of potash is an unnecessary constituent, being only added in order to facilitate the purification of the compound from iron; for in consequence of the ready crystallizability of alum, this salt is easily purified. Nevertheless, Wissmann has succeeded in removing the iron from the crude solution of sulphate of alumina obtained by treating clay with sulphuric acid, by adding ferrocyanide of potassium, which throws down the iron as Prussian blue; the solution, when evaporated to dryness, is found to consist of sulphate of alumina, containing about 7 per cent. of potash-alum. 1,500 tons of this article were produced at Newcastle-on-Tyne alone in the year 1854. See also ALUM.—H. M. W.

ALUMINIUM. (Syn. Al, equi, 137.) The name Aluminium is derived from the Latin alumen, for alum, of which salt this metal is the notable constituent.

The following is the method described by M. Deville for the preparation of this interesting metal:—

Having obtained the chloride of aluminium, he introduces into a wide glass (or porcelain) tube 200 or 500 grammes of this salt between two plugs of asbestos, (or in a boat of porcelain or even copper,) allows a current of hydrogen to pass from the generator through a desiccating bottle containing sulphuric acid and tubes containing chloride of calcium, and finally through the tube containing the chloride; at the same time applying a gentle heat to the chloride, to drive off any free hydrochloric acid which might be formed by the action of the air upon it. He now introduces at the other extremity of the tube a porcelain boat containing sodium; and when the sodium is fused the chloride of aluminium is heated, until its vapor comes in contact with the fused sodium. A powerful reaction ensues, considerable heat is evolved, and by continuing to pass the vapor of the chloride over the sodium until the latter is all consumed, a mass is obtained in the boat of the double chloride of aluminium and sodium, (NaCl, AlFCl₃) in which globules of the newly reduced metal are suspended. It is allowed to cool in the hydrogen, and then the mass is treated with water, in which the double chloride is soluble, the globules of metal being unacted upon.

These small globules are finally fused together in a porcelain crucible, by heating them strongly under the fused double chloride of aluminium and sodium, or even under common salt.

This process, which succeeds without much difficulty on a small scale, is performed far more successfully as a manufacturing operation. Two cast-iron cylinders are now employed instead of the glass or porcelain tube, the anterior one of which contains the chloride of aluminium, whilst in the posterior one is placed the sodium in a tray, about 10 lbs. being employed in a single operation. A smaller iron cylinder intermediate between the two former is filled with scraps of iron, which serve to separate iron from the vapor of chloride of

* Chemical Society's Quarterly Journal, vl. 216.
aluminium, by converting the perchloride of iron into the much less volatile protochloride. They also separate free hydrochloric acid and chloride of sulphur.

During the progress of the operation the connecting tube is kept at a temperature of about 400° to 600°, but both the cylinders are but very gently heated, since the chloride of aluminium is volatile at a comparatively low temperature, and the reaction between it and the sodium when once commenced generates so much heat that frequently no external aid is required.

Preparation of Aluminium by Electrolysis.—Mr. Gore has succeeded in obtaining plates of copper coated with aluminium by the electrolysis of solutions of chloride of aluminium, acetate of aluminas, and even common alum; but the unalloyed metal cannot be obtained by the electrolysis of solutions. Deville, however, produced it in considerable quantities by the method originally suggested by Bunsen, viz., by the electrolysis of the fused double chloride of aluminium and sodium, (NaF, AlF₃); but since this process is far more troublesome and expensive than its reduction by sodium, it has been altogether superseded.

Preparation of Aluminium from Kryolite.—So early as March 30, 1855, a specimen of aluminium was exhibited at one of the Friday evening meetings of the Royal Institution, which had been obtained in Dr. Perrey's laboratory by Mr. Allan Dick, by a process entirely different from that of Deville, which promised, on account of its great simplicity, to supersede all others. It consisted in heating small pieces of sodium, placed in alternate layers with powdered kryolite, a mineral now found in considerable abundance in Greenland, which is a double fluoride of aluminium and sodium, analogous to the double chloride of aluminium and sodium, its formula being NaF, AlF₃. The process has the advantage that one of the materials is furnished readily formed by nature.

The experiment was only performed on a small scale by Mr. Dick in a platinum crucible lined with magnesia; the small globules of metal, which were obtained at the bottom of the mass of fused salt, being subsequently fused together under chloride of potassium or common salt.

Before the description of these experiments was published, M. Rose, of Berlin, published a paper in September, 1855, on the same subject. In Rose's experiments he employed east-iron crucibles, in which were heated ten parts of a mixture of equal weights of kryolite and chloride of potassium with 2 parts of sodium. The aluminium was obtained in small globules, which were fused together under chloride of potassium, as in Mr. Dick's experiments.

Rose experienced a slight loss of aluminium by fusion under chlorides of potassium, and found it more advantageous to perform this fusion under a stratum of the double chloride of aluminium and sodium, as Deville had done.

He never succeeded in extracting the whole quantity of aluminium present in the kryolite, (13 per cent.,) chiefly on account of the ready oxidizability of the metal when existing in a very finely divided state, as some of it invariably does.

It does not appear that any attempt has since been made to obtain aluminium on the large scale from kryolite, probably from the supply of the mineral not proving so abundant as was at one time anticipated.

In all the processes which have been found practicable on any considerable scale, for the manufacture of aluminium, the powerful affinities of sodium are employed for the purpose of eliminating it from its compounds. The problem of the diminution of the price of aluminium therefore resolves itself into the improvement of the methods for procuring sodium, so as to diminish the cost of the latter metal. M. Deville's attention was therefore directed, in the early steps of the inquiry, to this point; and very considerable improvements have been made by him, which will be found fully described under the head of Sodium.

Deville has since suggested the employment at once of the double salt of chloride of aluminium and chloride of sodium, (NaCl, AlF₃,) instead of the simple chloride of aluminium, so as to obtain the metal by means of sodium. He uses 400 parts of this double salt, 200 of common salt, 200 of flor spar, and 75 to 80 of sodium. The above-mentioned salts are dried, powdered, and mixed together; then with these the sodium, in small pieces, is mixed, and the whole heated in a crucible under a layer of common salt. After the reaction is complete, the heat is raised so as to promote the separation of the aluminium in the form of a button. It was found, however, that kryolite was, with advantage, substituted for the flor spar.

C. Brunner employs artificially prepared fluoride of aluminium but this method cannot offer any advantage over the employment of the chloride, which is cheaper, or the kryolite, which nature affords.

Properties.—The metal is white, but with a bluish tinge; and even when pure has a lustre far inferior to silver.
ALUMINIUM.

Specific gravity, 2.66, and, when hammered, 2.97.
Conducts electricity eight times better than iron, and is freely magnetic.
Its fusing point is between the melting points of zinc and silver.

By electrolysis it is obtained in forms which Deville believes to be regular octahedra; but Rose, who has also occasionally obtained aluminium in a crystalline state, (from kryolite,) denies that they belong to the regular system.

When pure, it is unoxidized even in moist air; but most of the commercial specimens (probably from impurities present in the metal) become covered with a bluish-gray tarnish. It is unaffected by cold or boiling water; even steam at a red heat is but slowly decomposed by it.

It is not acted upon by cold nitric acid, and only very slowly dissolved even by the boiling acid; scarcely attacked by dilute sulphuric acid, but readily dissolved by hydrochloric acid, with evolution of hydrogen.

Sulphuretted hydrogen and sulphides have no action upon it; and it is not even attacked by fused hydrated alkalies. Professor Wheatstone* has shown that in the voltaic series, aluminium, although having so small an atomic number, and so low a specific gravity, is more electro-negative than zinc; but it is positive to cadmium, tin, lead, iron, copper, and platinum.

Impurities in Aluminium.—Many of the discrepancies in the properties of aluminium, as obtained by different experimenters, are due to the impurities which are present in it.

If the napthala be not carefully removed from the sodium, the aluminium is liable to contain carbon.

Frequently, in preparing aluminium, by the action of the chloride on sodium, by Deville's original process, copper boats have been used for holding the sodium; in this case the metal becomes contaminated, not only with copper, but also with any other metal which may be present in the copper—e. g. Salu-Horstman † found copper in the aluminium sold in Paris, and Erdmann detected zinc; ‡ and in every case the metal is very liable to become mixed with silicon, either from the earthenware tubes, boats, or crucibles; hence Salvetat found, even in the aluminium prepared by Deville himself, 2.87 per cent. of silicon, 2.40 of iron, 0.28 of copper, and traces of lead.

The following analysis of commercial aluminium was communicated to the British Association, at its meeting in 1857, by Professor Mallet:—

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<tr>
<td>92-969</td>
<td>4-882</td>
<td>2-149</td>
<td>trace</td>
<td>96-253</td>
<td>3-293</td>
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Alloys of Aluminium.—Very small quantities of other metals suffice to destroy the malleability and ductility of aluminium. An alloy containing only \( \frac{1}{20} \) of iron or copper cannot be worked, and the presence of \( \frac{3}{20} \) copper renders it as brittle as glass. Silver and gold produce brittleness in a less degree. An alloy of 5 parts of silver with 100 of aluminium, is capable of being worked like the pure metal, but it is harder, and therefore susceptible of a finer polish; whilst the alloy, containing 10 per cent. of gold, is softer, but, nevertheless, not so malleable as the pure metal. The presence of even \( \frac{1}{40} \) part of bismuth renders aluminium brittle in a high degree.

These statements by Tissier,§ however, require confirmation; for Debray states that aluminium remains malleable and tough when containing as much as 8 per cent. of iron, or 10 per cent. of copper, but that a larger quantity of either of these metals renders it brittle.

It is curious that only 2 per cent. of silver are sufficient to give aluminium the brilliance and color of pure silver, over which the alloy has the great advantage of not being blackened by sulphuretted hydrogen.

On the other hand, small quantities of aluminium combined with other metals change their properties in a remarkable manner. Thus copper alloyed with only \( \frac{1}{20} \) of its weight of aluminium has the color and brilliance of gold, and is still very malleable, (Tissier;) and when the aluminium amounts only to \( \frac{1}{50} \), (i. e. 20 per cent.), the alloy is quite white, (Debray.)

An alloy of 90 parts of copper and 10 of aluminium is harder than common bronze, and is capable of being worked at high temperatures easier than the best varieties of iron. Larger quantities of aluminium render the metal harder and brittle.—Debray.

An alloy of 100 parts of silver with 5 of aluminium is as hard as the alloy employed in

* Phil. Mag. x. 143.
† Journal pr. Chem. lxv. 494.
‡ Comptes Rendus, xiii. 325.
the silver coinage, although the other properties of the silver remain unchanged, (Tissier.)

Similar alloys have likewise been prepared by Dr. Verwy.*

Moore, Calvert and Johnson describe an alloy of 25 parts aluminium to 75 of iron, which has the valuable property of not oxidizing by exposure to moist air.

Uses of Aluminium.—No very important application of aluminium has yet been made, although, at the time M. Deville’s experiments were commenced, sanguine hopes were entertained that aluminium might be produced at a price sufficiently low to admit of its practical application on a large scale; these anticipations have not been realized; and as yet, on account chiefly of its high price, the applications which have been made of this interesting metal are but few.

Its low specific gravity, combined with sufficient tenacity, recommends it for many interesting uses. The fractional weights used by chemists, which are made of platinum, are so extremely small that they are constantly being lost; their much greater volume in aluminium renders this metal peculiarly suitable. In the construction of the beams of balances, strength combined with lightness are desiderata; and M. Deville has had very beautiful balance beams made of this metal; but at present its high price has prevented their extensive adoption.

These same qualities render this metal suitable for the construction of helmets and other armor; but at present these are but curiosities, and are likely to remain so, unless some cheaper method of eliminating the metal than by the agency of sodium be discovered.

Its quality of being unacted upon by oxygen, sulphuretted hydrogen, and many acids, would suggest numerous applications, if it were sufficiently cheap; or, g. it might be used for coating other metals, as iron, lead, &c., to protect them from rust, instead of paint. It would be particularly useful for covering the pipes and cisterns employed in water supply, and thus preventing the accidents which are constantly resulting from the action of water on lead.

This metal has been proposed for making spoons, &c., instead of silver. It certainly has the advantage of not being blackened by sulphuretted hydrogen; but those which the writer has seen have a dull leaden hue,—for inferior, even, to somewhat tarnished silver in brilliancy,—and would certainly not be held in high esteem by the public.

It has been suggested to employ aluminium, on account of its sonorosity and ductility, for making piano-forte wires. It was also imagined that it might be used in making bells; but Mr. Denison has quite set this question at rest. No one who heard the sound of his aluminium bell will again think of such an application.

Probably one of the most interesting of the applications of aluminium (at least in a scientific point of view) that has been made, is the recent one by Deville and Wöhler, of employing it in the production of crystalline allotropic modifications of certain other elements hitherto unknown in that state; e. g. boron, silicon, and titanium, (which see.) It depends upon the fact that these elements, in the amorphous state, dissolve in fused aluminium, and, on cooling the molten solution, they slowly separate from the aluminium in the crystalline state.

Our first importation of aluminium was in 1856, to the value of 235. —II. M. W.

ALUMINIUM, CHLORIDE OF, (APCF—132.9.) Preparation.—Chloride of aluminium cannot be prepared by treating alumina with hydrochloric acid, as in the case of most chlorides; for on evaporating the solution to dryness, hydrochloric acid is evolved and alumina alone remains.

The method at present used is, in principle, the same as that originally suggested by Brasted, which has since found numerous other applications. It is impossible to convert alumina into the chloride by the direct action of chlorine alone; at any temperature the chlorine is as incapable of displacing the oxygen from the alumina as it would from lime. But if the attraction of the chlorine for the metal be supported by the affinity of carbon for the oxygen, then the compound is, as it were, torn asunder, carbonic acid or carbonic oxide resulting on the one hand, and the chloride of aluminium on the other.

On the large scale the chlorine is passed over a previously ignited mixture of clay and coal tar, contained in retorts like those used in the manufacture of coal gas, which are heated in a furnace; the chloride, which on account of its volatility is carried off, being condensed in a chamber lined with plates of earthenware, where it is deposited in a crystalline mass.

Properties.—It is a yellowish crystalline solid, readily decomposed by the moisture of the air into hydrochloric acid and alumina, volatile at a dull red heat. It is very soluble in water, but cannot be recovered by evaporating the solution.—II. M. W.

ALUM, NATIVE. This term includes several compounds of sulphate of alumina with the sulphate of some other base, as magnesia, potash, soda, the protoxides of iron, manganese.

—Proceedings of the Royal Institution, March 14, 1856.

The present price of Aluminium in London is 5s. per ounce, whilst only in March, 1856, just after M. Deville’s experiments had been made, it was 5s. per ounce.

It is calculated that more than a million sterling is annually expended in the metropolis on the paint necessary to protect the iron-work from decay.—Rec. J. Burton.
ALUM SHALE.

They occur generally as efflorescences, or in fibrous masses; when crystallized, they assume octahedral forms.

Native alum is soluble in water, and has an astringent taste, like that of the alum of commerce.—H. W. B.

The chief natural source from which the alum of commerce is derived in this country. It occurs in a remarkable manner near Whitby, in Yorkshire, and at Hurlet and Campsie, near Glasgow. A full description of the alum shale, and of the processes by which the crystallizable alum is separated, will be found under ALUM.

Some amalgams are solids and others fluids; the former are often crystalline, and the latter may be probably regarded as the solid amalgam dissolved in mercury.

Silver Amalgam may be formed by mixing finely-divided silver with mercury. The best process is to precipitate silver from its solution by copper, when we obtain it in a state of fine powder, and then to mix it with the mercury.

A native amalgam of mercury and silver occurs in fine crystals in the mines of the Palatinate of Moschellandsberg: it is said to be found where the veins of copper and silver intersect each other. Dana reports its existence in Hungary and Sweden, at Allenmont, in Dauphiné; Almaden, in Spain, and in Chili; and he quotes the following analyses:

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<tr>
<th>Silver</th>
<th>Mercury</th>
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<tr>
<td>Moschellandsberg</td>
<td>36.0</td>
</tr>
<tr>
<td>Ditto</td>
<td>23.0</td>
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<tr>
<td>Allenmont</td>
<td>27.5</td>
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If six parts of a saturated solution of nitrate of silver with two parts of a saturated solution of the protonitrate of mercury are mixed with an amalgam of silver one part and mercury seven, the solution is speedily filled with beautiful baroerose crystals—the Arbor Dionae, the tree of Diana,—or the silver tree.

Gold Amalgam is made by heating together mercury with grains of gold, or gold-foil; when the amalgam of gold is heated, the mercury is volatilized and the gold left. This amalgam is employed in the process known as that of fire-gilding, although, since electro-gilding has been introduced, it is not so frequently employed. A gold amalgam is obtained from the platinum region of Columbia; and it has been reported from California, especially near Mariposa. Schneider gives its composition, mercury, 57-40; gold, 38-89; silver, 5-9.

Tin Amalgam.—By bringing tin-foil and mercury together, this amalgam is formed, and is used for silvering looking-glasses. (See Silvering Glass.) If melted tin and mercury are brought together in the proportion of three parts mercury and one part tin, the tin amalgam is obtained in cubic crystals.

Electrique Machine Amalgam.—Melt equal parts of tin and zinc together, and combine these with three parts of mercury: the mass must be shaken until it is cold; the whole is then rubbed down with a small quantity of lard, to give it the proper consistence.

Amalgam Copper, for stopping teeth. The French dentists have long made use of this for stopping teeth. It is sold in small rolls of about a drachm and a half in weight; it is covered with a grayish tarnish, has a hardness much greater than that of bone, and its cohesion and solidity are considerable. When heated nearly to the point of boiling water, this amalgam swells up, drops of mercury exuding, which disappear again on the cooling of the substance. If a piece, thus heated, be rubbed up in a mortar, a plastic mouldable mass, like poor clay, is obtained, the consistence of which may, by continued kneading, be increased to that of fat clay. If the moulded mass be left for ten or twelve hours, it hardens, acquiring again its former properties, without altering its specific gravity. Hence, the stopping, after it has hardened, remains tightly fixed in the hollow of the tooth. The softening and hardening may be repeated many times with the same sample. Pettenkofer ascribes these phenomena to a state of amorphism, with which the amalgam passes from the crystalline condition in the process of softening. All copper amalgams containing between 0:25 to 0:30 of copper exhibit the same behavior. The above chemist recommends as the best mode of preparing this amalgam, that a crystalline paste of sulphate of suboxide of mercury (prepared by dissolving mercury in hydrated sulphuric acid at a gentle heat) be saturated under water at a temperature of from 60° to 70°, with finely divided regular copper, (prepared by precipitation from sulphate of copper with iron,) One portion of the copper precipitates the mercury, with formation of sulphate of copper; the other portion yields with mercury an amalgam: 100 parts of dissolved mercury require the copper precipitated by iron, from 232-2 parts of sulphate of copper. As in dissolving the mercury the protoxide is easily formed instead of the suboxide, particularly if too high a temperature be maintained, it is advisable, in order to avoid an excess of mercury in the amalgam, to take 232 parts of sulphate of copper, and to add to the washed amalgam, which is kept stirred, a quantity of mercury in minute portions, corresponding to the
AMMONIA.

amount of suboxide contained in the mercury salt, until the whole has become sufficiently plastic. This amalgam may be obtained by moistening finely-divided copper with a few drops of a solution of nitrate of suboxide of mercury, and then triturating the metal with mercury in a warmed mortar. The rubbing may be continued for some time, and may be carried on under hot water, mercury being added until the required consistence is attained.

A remarkable depression of temperature during the combination of amalgams has been observed by several chemists. Dobereiner states that when 816 grains of amalgam of lead (404 mercury and 412 lead) were mixed, at a temperature of 68°, with 688 grains of the amalgam of bismuth, (404 mercury and 284 bismuth,) the temperature suddenly fell to 50°, and by the addition of 808 grains of mercury (also at 68°) it became as low as 17°; the total depression amounting to 81°.

In certain proportions of mixture of the constituents of fusible metal (tin, lead, and bismuth) with mercury, Dobereiner formed surprising depressions of temperature; the temperature, however, of one experiment, sank instantly from 65° to 14°.

AMBER VARNISH. Amber is composed of a mixture of two resins, which are soluble in alcohol and ether, and in some of the recently-discovered hydro-carbon compounds. Varnishes are therefore prepared with them, and sold under the name of amber spirit varnishes; but these are frequently composed of either copal or mastic. They have been much used for varnishing collection pictures.

AMBERGRIS. It is found on various parts of the east coast of Africa, as well as in the eastern seas. The best is ash-colored, with yellow or blackish veins or spots, scarcely any taste, and very little smell unless heated or much handled, when it yields an agreeable odor. Exposed in a silver spoon it melts without bubble or scum, and on the heated point of a knife it vaporizes completely away.

The chemical composition of ambergris is represented by the following formula, C_2H_5O. True ambergris is very rarely met with, by far the largest proportion of that which is sold as ambergris being a preparation scented with rectol or musk.

In France the duty upon ambergris is 62 francs per kilogramme when imported in French vessels, and 67 francs when imported in foreign vessels.

Ambergris is at this time (1858) worth 16s. an ounce in England. Mr. Temple, of Belize, British Honduras, speaks of an odorous substance thrown off by the alligator, which appears to resemble ambergris.

AMETHYST. (Améthyste occidentale, Fr.; Eisenkiesel, Germ.) One of the vitreous varieties of quartz, composed of pure silica in the insoluble state—that is, it will not dissolve in a potash solution. It belongs to the rhombohedral system, and is found either in groups of crystals or lining the interior of geodes and pebbles. It is infusible before the blowpipe, and is not affected by acids. It is of a clear purple or bluish-violet tint; but the color is frequently irregularly diffused, and gradually fades into white. The color is supposed to be due to the presence of a small percentage of manganese, but Heinze attributes it to a compound of iron and soda. The amethyst, from the beauty of its color, has always been esteemed and used in jewellery. It was one of the stones called by the ancients ágathor-ros, a name which they conferred on it from its supposed power of preserving the wearer from intoxication. The most beautiful specimens are procured from India, Ceylon, and Persia, where they occur in geodes and pebbles: it is also found at Oberstein, in Saxony; in the Palatinate; in Transylvania; near Cork, and in the Island of May, in Ireland.

—H. W. B.

AMETHYST, ORIENTAL. (Améthyste orientale, Fr.; Démantspath, Germ.) This term is applied to those varieties of corundum which are of a violet color. See CORUNDUM.

—H. W. B.

AMANTHUS is the name given to the whiter and more delicate varieties of asbestos, which possess a satin-like lustre, in consequence of the greater separation of the fibres of which they are composed. A variety of amanthus (the amanthilode of Halley) is found at Osians, in France, the fibres of which are in some degree elastic. The word amanthus (from àmannos, unfeathered) is expressive of the easy manner by which, when soiled, it may be cleansed and restored to its original purity, by being heated to redness in a fire. See AMESSTR.—H. W. B.

AMMONIA. NH_3, cpy. 17. (Amononique, Fr.; Amonium, Germ.) The name given to the alkaline gas which is the volatile alkali of the early chemists. The real origin of this word is not known. Some suppose it to be from Amon, a title of Jupiter, near whose temple in Upper Egypt it was generated. Others suppose it to be from Amonuion, a Cyrenaic territory; whilst others again have deduced it from ammos, sand, as it was found in sandy ground.

It is probable that Pliny was acquainted with the pungent smell of ammonia. Dr. Black, in 1765, first isolated it, proving the distinction between it and its carbonate, with which it had been confounded up to that time; and it was soon afterwards more fully investigated by Priestley.
Ammonia being a product, not only of the destructive distillation of organic bodies containing nitrogen, but also of their decay, it exists in the atmosphere, in a large amount, if considered in the aggregate, although, by examining any particular specimen of air, the quantity appears small. Nevertheless, this small quantity of ammonia would seem to be exceedingly important in developing the nitrogenized constituents of plants. Liebig believes that the nitrogen of plants is exclusively derived from the ammonia present in the air; but the opinions of chemists are divided on this point. Boussingault * supports Liebig's view, but it is opposed by Mulder and Ville.

From the air, ammonia and its salts are carried down by the rain. This fact has been placed beyond all doubt by Liebig; and even the variations in the quantity have been determined by Boussingault, and more recently by Mr. Way. By the rain water it is carried into rivers, and ultimately into the sea, in which chloride of ammonium has been detected by Dr. Marine. It has likewise been detected in mineral springs, especially brine springs, and even in common salt.—*Vogel.

Ammonia is present in the exhalations from volcanoes. During the eruption of Vesuvius in 1794, the quantity of sal ammoniac discharged by the mountain was so great, that the peasants collected it by hundredweights, (Bischof; * ) and in the last eruption of Hecla, in Sept., 1845, a similar phenomenon was observed; and, according to Ferrara, it is sometimes found in such quantity at Elma, that a very profitable trade has been carried on in it. Dr. Daubeney thinks that the volcanic ammonia is produced by the action of water upon mineral nitrates, (perhaps the nitrates of silicon,) similar in properties to the nitrates of Titanium and Boron, which have been recently more carefully examined by M. St. Claire Deville. Ammoniacal salts have likewise been found as a sublimate arising from the combustion of coal strata.

The great supply of ammonia and its salts is derived from the destructive distillation of organic bodies, animal and vegetable, containing nitrogen; but its salts exist in plants, and to a much larger extent in the liquid and solid excrements of animals. As a urate, it forms the chief constituent of the excrement of the box, as well as that of many birds, hence the large quantity of ammoniacal salts in guano. See Guano.

**Formation of Ammonia.**—No process has yet been devised for inducing the direct combination of nitrogen and hydrogen to produce ammonia; but under the disposing influence of the production of other compounds, in the presence of these elements, as well as when these gases are presented to each other in the nascent state, their union is effected.

Thus, when electric sparks are passed through a mixture of nitrogen and oxygen in the presence of hydrogen and aqueous vapor, nitrate of ammonia is generated. If, while zine is being dissolved in sulphuric acid, nitric acid be added, much ammonia is formed, (Yetzitz: *) so again, if hydrogen and binoxide of nitrogen be passed over spongy platinum, torrents of ammonia are produced, the hydrogen converting the oxygen of the binoxide into water, when the nitrogen, at the moment of its liberation, combines with the hydrogen to form ammonia.

It has even been proposed to carry out this last method on a manufacturing scale.

Messes. Crane and Jullien, in their patent of January 18, 1848, describe a method of manufacturing ammonia in the state of carbonate, hydroxyeanate, or free ammonia, by passing any of the oxygen compounds of nitrogen, together with any compound of hydrogen and carbon, or any mixture of hydrogen with a compound of carbon or even free hydrogen, through a tube or pipe containing any catalytic or contact substance, as follows:—Oxides of nitrogen, (such, for instance, as the gases liberated in the manufacture of oxalide acid,) however procured, are to be mixed in such proportion with any compound of carbon and hydrogen, or such mixture of hydrogen and carbonic oxide or acid as results from the contact of the vapor of water with ignited carbonaceous matters, and the hydrogen compound or mixture containing hydrogen may be in slight excess, so as to ensure the conversion of the whole of the nitrogen contained in the oxide so employed into either ammonia or hydrocyanic acid, which may be known by the absence of the characteristic red fumes on allowing some of the gaseous matter to come in contact with atmospheric air. The catalytic substance which Messrs. Crane and Jullien prefer is platinum, which may be in the state of sponge, or it may be asbestos coated with platinum. This catalytic substance is to be placed in a tube, and heated to about 600° F., so as to increase the temperature of the product, and at the same time prevent the deposition of carbonate of ammonia, which passes downwards into a vessel of the description well known and employed for the purpose of condensing carbonate of ammonia. The condenser for this purpose must be furnished with a safety pipe, to allow of the escape of uncondensed matter, and made to drip into a solution of any substance capable of combining with hydroxyeanate or ammonia where they would be condensed. A solution of salt of iron is preferable for this purpose.†

**Chemical Character.**—The gaseous ammonia liberated from its salts by lime (in a manner to be afterwards described) is a colorless gas of a peculiar pungent odor. It is composed, by weight, of 1 equivalent of nitrogen and 3 of hydrogen; or, by volume, of 2

* Annales de Chimie et de Physique, xiii. 149.
† Pharm. Journ. xiii. 114.
AMMONIA.

measures of nitrogen and 6 of hydrogen, condensed to four; and may be resolved into these constituent gases by passing over spongy platinum heated to redness. By a pressure of 0.5 atmospheres at 50° F., it is condensed into a colorless liquid. It is combustible, but less so than hydrogen, on account of the incombustible nitrogen which it contains; but its inflammability may be readily seen by passing it into an argand gas flame reduced to a minimum.

Upon this variation in density of solutions of ammonia in proportion to their strength, Mr. J. J. Griffin has constructed a useful instrument called an Ammonia-metre. It is founded upon the following facts:—That mixtures of liquid ammonia with water possess a specific gravity which is the mean of the specific gravities of their components; that in all solutions of ammonia, a quantity of anhydrous ammonia, weighing 212 grains, which he calls a test-atom, displaces 300 grains of water, and reduces the specific gravity of the solution to the extent of 0.00125; and, finally, that the strongest solution of ammonia which it is possible to prepare at the temperature of 62° F., contains in an imperial gallon of solution 100 test-atoms of ammonia.

We extract the following paragraph from Mr. Griffin’s paper in the Transactions of the Chemical Society, explanatory of the accompanying Table:—

"The first column shows the specific gravity of the solutions; the second column the weight of an imperial gallon in pounds and ounces; the third column the percentage of ammonia by weight; the fourth column the degree of the solution, as indicated by the instrument, corresponding with the number of test-atoms of ammonia present in a gallon of the liquor; the fifth column shows the number of grains of ammonia contained in a gallon; and the sixth column the atomic volume of the solution, or that measure of it which contains one test-atom of ammonia. For instance, one gallon of liquid ammonia, specific gravity 880, weighs 8 lbs. 128 oz. avoirdupois; its percentage of ammonia, by weight, is 33.117; it contains 96 test-atoms of ammonia in one gallon, and 20400.0 grains of ammonia in one gallon; and, lastly, 104.16 septems containing one test-atom of ammonia. Although no hydrometer, however accurately constructed, is at all equal to the Centigrade mode of chemical testing, yet the Ammonia-meter, and the Table accompanying it, will be found very useful to the manufacturer, enabling him not only to determine the actual strength of any given liquor, but the precise amount of dilution necessary to convert it into a liquor of any other desired strength, whilst the direct quotation of the number of grains of real ammonia contained in a gallon of solution of any specific gravity will enable him to judge at a glance of the money-value of any given sample of ammonia.

Table of Liquid Ammonia, (Griffin.)

One Test-Atom of Anhydrous Ammonia = NH₃ weighs 212.5 grains.

Specific Gravity of Water = 100000. One Gallon of Water weighs 10 lbs. and contains 10,000 Septems. Temperature 62° F.

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**AMMONIA.**

*Table of Liquid Ammonia, (continued.)*

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Ammonial gas combines directly with hydrated acids, forming a series of salts, the constitution of which is peculiar, and must be here briefly discussed, that the formula hereafter employed in describing them may be understood.

These compounds may be viewed as direct combinations of the ammonia with the hydrated acids; thus, the compound with Hydrochloric acid as the Hydrosulphuric acid " Sulphuric acid " Nitric acid " Carbonic acid "

Hydrochlorate, (NH₄ Cl.) Hydrosulphate, (NH₄ HS.) Hydrated sulphate, (NH₄ SO₄.) Hydrated nitrate, (NH₄ NO₃.) Hydrated carbonate, (NH₄ ; HO, CO₃.).

But the close analogy of these compounds, in all their properties, to the corresponding salts of potash and soda has led chemists to the assumption of the existence of a group of elements possessing the characters of a metal, of a basyl or hypothetical metallic radical, called ammonium, (NH₄ ) in these salts; which theory of their constitution brings out the resemblance to the potash and soda salts more clearly, thus:—

The chloride of potassium contains KCl. And the chloride of ammonium contains NH₄ Cl.

— sulphide of potassa " " KO, SO₄. — sulphide of ammonia NH₄ O, SO₄ .
— nitrate " " " KO, NO₃. — nitrate " " NH₄ O, NO₃ .
— carbonate " " " KO, CO₃. — carbonate " " NH₄ O, CO₃ .

Although it may be objected to this view that the metal ammonium is not known, yet a curious metallic compound of this metal with mercury has been obtained; and, after all, it is by no means necessary that the metal should be isolated, for already the existence of numerous basic radicals has been assumed in organic chemistry which have never been isolated.

It is true, also, that the oxide of ammonium is unknown, but substitution-products of it have been produced, which are solid bodies, soluble in water, exhibiting all the characters of potash solution, being as powerfully caustic and alkaline. In fact, ammonia is in reality but the type of a vast number of compounds. It is capable of having its hydrogen replaced by metals, (as copper, mercury, calcium, &c.,) as well as by metallic or basic compound radicals, producing the endless number of artificial organic bases, which are primary, secondary, or tertiary nitrides, according as one, two, or three equivalents of the ammonia are replaced. When the substitution of the hydrogen in ammonia is effected by acid radicals, the compounds are called amides.

Preparation of Ammonia.—Ammonia is obtained by the decomposition of one of the
AMMONIA, CARBONATE OF.

salts of ammonia, either the chloride of ammonium, NH\(_4\)Cl, (sal ammoniac,) or the sulphate, by a metallic oxide, e. g. lime.

\[ \text{NH}_4\text{Cl} + \text{CaO}, \text{HO} = \text{CaCl} + \text{NH}_3 + 2\text{HO}. \]

On the small scale in the laboratory the powdered ammonical salt is mixed with slaked lime, in a Florence flask or a small iron retort, and gently heated; the ammonical gas being dried by passing it through a bottle containing lime. Chloride of calcium must not be employed in the desiccation of ammonia, since the ammonia is absorbed by this salt, producing a curious compound, the chloride of caiammonium, \( \{ \text{NH}_4 \} \{ \text{Ca} \} \), being, in fact, one of those substitution-compounds before alluded to.

The gaseous ammonia must be collected over mercury, on account of its solubility in water. This operation is carried out on the large scale for the purpose of making the aqueous solution of ammonia, (lique ammonia, or spirits of hartshorn.)

Solution of Ammonia.

Preparation.—In preparing the aqueous solution, the gas is passed into water contained in Woolfe's bottles, which on the small scale are of glass, whilst on the large scale they are made of earthenware.

A sufficiently eapacious retort of iron or lead should be employed, which is provided with a movable neck; and it is desirable to pass the gas through a worm, to cool it, before it enters the first Woolfe's bottle. Each of the series of Woolfe's bottles should be furnished with a safety-funnel in the third neck, to avoid accidents by absorption. The whole of the condensing arrangements should be kept cool by ice or cold water.

Properties.—In the London and in the Edinburgh "Pharmacopoeia" two solutions of ammonia are directed to be prepared, the stronger having the specific gravity 0-982, and containing about 20 per cent. of ammonia; the weaker of specific gravity 0-960, containing, therefore, about 10 per cent. of the gas.

Sometimes the commercial solution of ammonia is made by treating impure ammonical salts with lime, and it then contains empyreumatic oil; in fact, the various volatile products of the distillation of coal which are soluble in or miscible with water.

Pyrol may be detected in ammonia by the purple color which it strikes with an excess of nitric or sulphuric acid. If the residue of its distillation be mixed with potash, Picoline is detected by its peculiar odor. Naphthaline is discovered not only by its odor, but may also be separated by sublimation or heating, after converting the ammonia in the solution into a salt by sulphuric or hydrochloric acid.—Dr. Maclogan.

We imported into England of sulphate and liquor of ammonia as follows:—

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</tr>
<tr>
<td>&quot;</td>
<td></td>
<td>lbs. 23,904</td>
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<td>Ammonia, liquor</td>
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Since, for the purpose of purification on the large scale, ammonia is invariably converted into chloride or sulphate, the details of the manufacture of the ammonical salts will be given under those heads. For the determination of ammonia, see Nitrogen.—J. M. W.

AMMONIA, CARBONATE OF. (The sesquicarbonate of commerce, 2NH\(_4\), 3CO\(_2\), 2H\(_2\)=NH\(_4\)O, CO\(_3\); HO, CO\(_2\)=NH\(_4\)CO\(_3\), expr. 118.) This salt was probably known to Raymond Lully and Basil Valentine, as the chief constituent of putrified urine. The real distinction between ammonia and its carbonate was pointed out by Dr. Black.
AMMONIA, CARBONATE OF.

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Carbonate of ammonia is formed during the putrefaction of animal substances, and by their destructive distillation. Its presence in rain water has been before alluded to.

The carbonate of ammonia of commerce is obtained by submitting to sublimation a mixture either of sal ammoniac or sulphate of ammonia with chalk.

This is generally carried out in cast-iron retorts, similar in size and shape to those used in the manufacture of coal gas. The retorts are charged through a door at one end, and at the other they communicate with large square leaden chambers, supported by a wooden frame, in which the sublimed salt is condensed. Fig. 25.

The product of this first process is impure, being especially discolored by the presence of carbonaceous matter, and has to be submitted to resublimation. This is carried out in iron pots surmounted by movable leaden caps. These tops are either set in brickwork, and

heated by the flue of the retort furnace, or are placed in a water-bath, as shown in fig. 26. In fact, a temperature not exceeding 180° F. is found sufficient.

The charge of a retort consists usually of about 65 lbs. of sulphate of ammonia (or an equivalent quantity of the chloride) to 100 lbs. of chalk, which yield about 40 lbs. of crude carbonate of ammonia.

Modifications of the Process.—Mr. Laming has suggested to bring ammonia and carbonic acid gases into mutual contact in a leaden chamber having at the lower part a layer of water, and then to crystallize the salt by evaporating this aqueous solution.

He also proposes to prepare carbonate of ammonia from the sulphide of ammonium of gas liquors, by passing carbonic acid gas into the liquor, which carbonic gas is generated by heating a mixture of oxide of copper and charcoal, in the proportion of twelve parts of the former to one of the latter.

Mr. Hill has described his mode of obtaining sesquicarbonate of ammonia from guano.

To effect this, the guano is first mixed with charcoal or powdered coke; the mixture is then heated, and the sesquicarbonate of ammonia obtained by sublimation. The process does not appear to be much employed.

Manufacture of Ammonia from Peat and Shale.—Mr. Hills, in his patent of August 11th, 1846, specified the following method of obtaining ammonia from peat:—The peat is placed in an upright furnace and ignited; the air passes through the bars as usual, and the ammonia is collected by passing the products of combustion through a suitable arrangement of apparatus to effect its condensation. This plan of obtaining ammonia from peat appears to be precisely similar to that patented by Mr. Rees Reece, (January 29th, 1849,) and made to form an important feature in the operations of the British and Irish Peat Company.

The first part of Mr. Reece’s patent is for an invention for causing peat to be burned in a furnace by the aid of a blast, so as to obtain inflammable gases and tarry and other products from peat. For this purpose, a blast furnace with suitable condensing apparatus is used. The gases, on their exit from the condensing apparatus, may be collected for use as fuel or otherwise; and the tarry and other products pass into a suitable receiver. The tarry products may be employed to obtain paraflne and oils for lubricating machinery, &c.; and the other products may be made available for evolving ammonia, wood spirit, and other matters by any of the existing processes. Dr. Hodges, of Belfast, states that in his experiments he obtained nearly 23 1/2 lbs. of sulphate of ammonia from a ton of peat. Sir Robert Kane, who was employed by Government to institute a series of experimental researches on the products obtainable from peat, states that he obtained sulphate of ammonia at the rate of 24 3/4 lbs. per ton of peat. Messrs. Drew and Stockton patented, in 1846, the obtaining ammonia from peat by distillation in close vessels, as practiced in the carbonization of wood.
AMMONIA, NITRATE OF.

It will thus be seen that the peat is a source of ammonia, but that this source is a profitable or economical one, in a commercial point of view, is a problem in process of solution.

**Ammonia from Schist.** — Another source of ammonia is luminescent schist, which, when submitted to destructive distillation, gives off an ammoniacal liquor which may be employed in the manufacture of ammonical salts by any of the usual processes. The obtaining of ammonia from schist forms part of a patent granted to Count de Hombesch, September 4, 1841.

**Chemical Composition and Constitution.** — The true neutral carbonate of ammonia (NH₄O, CO₂) does not appear to exist. The sesquicarbonate of ammonia of the schists was found by Rose to have the composition assigned to it by Mr. Phillips, i.e. it contains 2NH₃, 3CO₂, 2HO; and it may therefore be viewed as a compound of the true bicarbonate, i.e. the double carbonate of ammonia and water, )NH₄O, CO₂; HO, CO₂, with a peculiar compound of anhydrous carbonic acid with ammonia itself, (NH₄, CO₂).

The equation representing its method of preparation will then be,

\[3\text{NH}_4\text{O}, \text{SO}_4 + 3\text{CaO}, \text{CO}_2 = (\text{NH}_4\text{O}, \text{CO}_2; \text{HO}, \text{CO}_2 + \text{NH}_4\text{O} + 3\text{CaO}, \text{SO}_4, \text{or} \quad 3\text{NH}_4\text{Cl} + 3\text{CaO}, \text{CO}_2 = (\text{NH}_4\text{O}, \text{CO}_2; \text{HO}, \text{CO}_2 + \text{NH}_4\text{O}, \text{CO}_2, \text{so}_{4}, \text{NH}_4\text{O}_2 + 3\text{CaCl}_2; \]

for it is invariable found that a certain quantity of water and ammonia is liberated during the distillation, and hence the anomalous character of the compound. In fact, in operating upon 3 equivalents of the sulphate or chloride of the 2 equivalents of the true carbonate of ammonia (NH₄O, CO₂) which may be supposed to be generated, two are decomposed, one losing an equivalent of ammonia, the other an equivalent of water; of course, the ammonia thus liberated is not lost; it is passed into water to be saturated with acid, and thus again converted into sulphate or chloride.

**Properties.** — Sesquicarbonate of ammonia (as it is commonly called) is met with in commerce in the form of soft fibrous white translucent cakes, about two inches thick.

When exposed to the air the constituents of the less stable compound NH₂, CO₂ are volatilized, and a white opaque mass of the true bicarbonate remains. Hence the odor of ammonia always emitted by the commercial carbonate. Mr. Scanlan has also shown that, by treatment with a small quantity of water, the carbonate is dissolved, leaving the bicarbonate. It is soluble in four times its weight of cold water, but boiling water decomposes it.

**Impurities.** — The commercial salt is sometimes contaminated with empyreumatic oil, which is recognized by its yielding a brownish-colored solution on treatment with water.

It may contain sulphate and chloride of ammonium. For the recognition of the presence of these acids, see SULPHURIC ACID.

Sulphide and hyposulphite of ammonia are sometimes present, and likewise lead, from the chambers into which the salt has been sublimed.

**Other Carbonates of Ammonia.** — Besides the neutral or monocarbonate of ammonia before alluded to, the true bicarbonate (NH₄O, CO₂; HO, CO₂) and the sesquicarbonate of the schists, Rose has described about a dozen other definite compounds; but, for their description, we must refer to Ure's "Dictionary of Chemistry."

**AMMONIA, NITRATE OF.** This salt crystallizes in six-sided prisms, being isomorphous with nitrate of potash.

Its composition is NH₄O, NO₂. It is incapable of existing without the presence of an equivalent of water, in addition to NH₂ and NO₂. If heat be applied, the salt is entirely decomposed into protoxide of nitrogen and water; thus—

\[\text{NH}_4\text{O}, \text{NO}_2 = 2\text{NO} + 4\text{H}_2\text{O}.\]

Besides its use in the laboratory for making protoxide of nitrogen, it is a constituent of frigoric mixtures, on account of the cold which it produces on dissolving in water.

Lastly, it is very convenient for promoting the deflagration of organic bodies, both its constituents being volatile on heating.

**AMMONIA, SULPHATE OF.** (NH₄O, SO₄) This salt is found native in fissures near volcanoes, under the name of mossaqnine, associated with sal ammoniac. It also forms in ignited coal-beds—as at Bradley, in Staffordshire—with chloride of ammonium.

This salt is prepared by saturating the solution of ammonia, obtained by any of the processes before described, (either from animal refuse, from coal, in the manufacture of coal-gas, from guano, or from any other source,) with sulphuric acid, and then evaporating the solution till the salt crystallizes out.

Frequently, instead of adding the acid to the ammoniacal liquor, the crude ammoniacal liquor is distilled in a boiler, either alone or with lime, and the evolved ammonia is passed into the sulphuric acid, contained in a large tun or in a series of Woolfe's bottles; or a modification of Coffey's still may be used with advantage, as in the case of the saturation of hydrochloric acid by ammonia.

If Coffey's still be employed, a considerable concentration of the liquor is effected during the process of saturation, which is subsequently completed generally in iron pans;
AMMONIA, SULPHATE OF.

but great care has to be taken not to carry the evaporation too far, to avoid decomposition of the sulphate by the organic matter invariably present, which reduces it to the state of sulphite, hyposulphite, and even to sulphide, of ammonium.

The salt obtained by this first crystallization is much purer than the chloride produced under similar circumstances, and one or two recrystallizations effect its purification sufficiently for all commercial purposes.

It is on account of the greater facility of purification which the sulphate affords by crystallization than the chloride of ammonium, that the former is often produced as a preliminary stage in the manufacture of the latter compound, the purified sulphate being then converted into sal ammoniac by sublimation with common salt. The acid mother-liquor left in the first crystallization is returned to be again treated, together with some additional acid, with a fresh quantity of ammonia.

Preparation. Modifications in details and patents.—Since it is in the production of the sulphate of ammonia that the modification of Coffey's still, called the ammonium still, is generally employed, it may be well to introduce here a detailed account of its arrangement.

This apparatus is an upright vessel, divided by horizontal diaphragms or partitions into a number of chambers. It is proposed to construct the vessel of wood, lined with lead, and the diaphragms of sheet iron. Each diaphragm is perforated with many small holes, so regulated, both with regard to number and size, as to afford, under some pressure, passage for the elastic vapors which ascend, during the use of the apparatus, to make their exit by a pipe opening from the upper chamber. Fitted to each diaphragm are several small valves, so weighted as to rise whenever elastic vapors accumulate under them in such quantity as to exert more than a certain amount of pressure on the diaphragm. A pipe also is attached to each diaphragm, passing from about an inch above its upper surface to the bottom of a cup or small reservoir, fixed to the upper surface of the diaphragms next underneath. This pipe is sufficiently large to transmit freely downwards the whole of the liquid, which enters for distillation at the upper part of the upright vessel; and the cup or reservoir, into which the pipe dips, forms, when full of liquid, a trap by which the upward passage of elastic vapors by the pipe is prevented. The vessel may rest on a close cistern, contrived to receive the descending liquid as it leaves the lowest chamber, and from this cistern it may be run off, by a valve or cock, whenever expedient. The cistern, or in its absence the lowest chamber, contains the orifice of a pipe which supplies the steam for working the apparatus. The exact number of chambers into which the upright vessel is divided is not of essential importance; but the quantity of liquid and the surface of each diaphragm being given, the distillation, within certain limits, will be more complete the greater the number of chambers used in the process. The liquid undergoing distillation in this apparatus necessarily covers the upper surface of each diaphragm to the depth of about an inch, being prevented from passing downward through the small perforations by the upward pressure of the rising steam and other elastic vapors; and, on the other hand, the steam being prevented, by the traps, from passing upwards by the pipes, is forced to ascend by the perforations in the diaphragms; so that the liquid lying on them becomes heated, and in consequence gives off its volatile matters. When the ammoniacal liquor accumulates on one of the diaphragms to the depth of an inch, it flows over one of the short pipes into the trap below, and overflows into the next diaphragm, and so on. See Distillation.

The management of the apparatus varies in some measure with the form in which it is desirable to obtain the ammonium. When the ammonium is required to leave the upper chamber in the form of gas, either pure or impure, it is necessary that the steam which ascends and the current of ammoniacal liquid which descends, should be in such relative proportions that the latter remain at or near the atmospheric temperature during its passage through some of the upper chambers, becoming progressively hotter as it descends, until it reaches the boiling temperature; in which state it passes through the lower chambers, either to make its escape, or to enter a cistern provided to receive it, and in which it may for some time be maintained at a boiling heat. On the contrary, if the ammonium, either pure or impure, be required to leave the upper chamber in combination with the vapor of water, the supply of steam entering below must bear such proportion to that of the ammoniacal liquid supplied above, that the latter may be at a boiling temperature in the upper part of the apparatus.

The use of this apparatus has been patented in the name of Mr. W. E. Newton, Nov. 9, 1841.

Mr. Hill's process, patented Oct. 19, 1848, for concentrating ammoniacal solutions, by causing them to descend through a tower of coke through which steam is ascending, is, in fact, nothing more than a rough mode of carrying out the same principle which is more effectually and elegantly performed by the modification of Coffey's still above described. The concentrated ammonia liquor is then treated with acid and evaporated in the usual way.

Mr. Wilson has patented, Dec. 7, 1850, another method of saturating the ammonia with

* Pharm. Journal, xiii. 64.
AMMONIUM.

the acid by passing the crude ammonia vapor, obtained by heating the ammoniacal liquor of the gas-works, in at the bottom of a high tower filled with coke, whilst the sulphuric acid descends in a continuous current from the top, in this manner the acid and ammonia are exposed to each other over a greatly extended surface.

Dr. Richardson (patent, Jan. 26, 1850) mixes the crude ammonia liquors with sulphate of magnesia, then evaporates the solution, and submits the double sulphate of magnesia and ammonia, which separates, to sublimation; but it would not appear that any great advantage is derived from proceeding in this way, either pecuniary or otherwise.

Mr. Leaming produces sulphurous acid through the gas liquor, and finally oxidizes the sulphite thus obtained to the state of sulphate, by exposure to the air. (Patent, Aug. 12, 1852.)

Michie's mode of obtaining sulphate of ammonia, patented April 30, 1850, is as follows:—The ammoniacal liquors of the gas-works are combined with sulphate and oxide of lead, which is obtained and prepared in the following way:—Sulphuret of lead in its natural state is taken and reduced to small fragments by any convenient crushing apparatus. It is then submitted to a roasting process, in a suitably arranged reverberatory furnace of the following construction:—The furnace is formed of two shelves, or rather the bottom of the furnace and one shelf, and there is a communication from the lower to the upper. The galena or sulphuret of lead, previously ground, is then spread over the surface of the upper shelf, to a thickness of about 2 or 2½ inches, and there it is submitted to the heat of the furnace. It remains thus for about two hours, at which time it is drawn off the upper shelf and spread over the lower shelf or bottom of the furnace, where it is exposed to a greater heat for a certain time, during which it is well stirred, for the purpose of exposing all the parts equally to the action of the heat, and at the same time the fusion of any portion of it is prevented. By this process the sulphuret of lead becomes converted partly into sulphate and partly into lead. This product of sulphate and oxide of lead is thus crushed by any ordinary means, and reduced to about the same degree of fineness as coarse sand. It is now to be combined with the ammoniacal liquors, when sulphate of ammonia and sulphur and carbonate of lead will be produced.

The sulphate of ammonia is separated by treatment with water, and the residuary mixture of sulphide and carbonate of lead is used for the manufacture of lead compounds.

The sulphite of ammonia obtained by either of the methods above described is a colorless salt, containing, according to Mitcherlich, one equivalent of water of crystallization. It is isomorphous with sulphate of potash.

It deliquesces by exposure to the air; 1 part dissolves in 2 parts of cold water, and 1 of boiling water. It fuses at 140° C. (284° F.), but at 280° C. (558° F.) it is decomposed, being volatilized in the form of free ammonia, sulphite, water, and nitrogen.

For the other sulphates—the sulphites and those salts which are but little used in the arts and manufactures—we refer to the "Dictionary of Chemistry."

Uses.—The chief consumption of ammoniacal salts in the arts is in the form of sal ammoniac, the sulphate of ammonia being principally used as a material for the manufacture of the chloride of ammonium. It may, however, be employed directly in making ammonium nitrate, or in the production of free ammonia by treatment with lime. AMMONIUM. (NH₄). The radical supposed to exist in the various salts of ammonia. Thus NH₄O is the oxide, NH₄Cl the chloride, of ammonium. Ammonium constitutes one of the best established chemical types. See Formule. Chemical.—C. G. W.

AMMONIUM, CHLORIDE OF. This salt is formed in the solid state by bringing in contact its two gaseous constituents, hydrochloric acid and ammonia. The gases combine with such force as to generate, not only heat, but sometimes even light. It may also be prepared by mixing the aqueous solutions of these gases, and evaporating till crystallization takes place.

When ammoniacal gas is brought into contact with dry chlorine, a violent reaction ensues, attended by the evolution of heat and even light. The chlorine combines with the hydrogen to produce hydrochloric acid, which unites with the remainder of the ammonia, forming chloride of ammonium, the nitrogen being liberated. The same reaction takes place on passing chlorine gas into the saturated aqueous solution of ammonia. Manufacture of Sal Ammoniac from Gas Liquor.—By far the largest quantity of the ammoniacal salts now met with in commerce is prepared from "gas liquor," the quantity of which annually produced in the metropolis alone is quite extraordinary—one of the London gas works producing in one year 324,800 gallons of gas liquor, by the distillation of 51,100 tons of coal; and the total consumption of coal in London for gas making is estimated at about 840,000 tons.

The principle of the conversion of the nitrogen of coal into ammonia by destructive distillation, as in the manufacture of coal gas, will be found described in connection with the processes of gas manufacture and the products produced by the destructive distillation of coal.

In the purification of the coal gas, the bodies soluble in water are all contained in the
AMMONIUM, CHLORIDE OF.

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"gas liquor," (see Coal Gas,) together with a certain quantity of tarry matter. The ammonia is chiefly present in the form of carbonate, together with certain quantities of chloride, sulphide, cyanide, and sulfo cyanide of ammonium, as well as the salts of the compound ammonias.

For the purpose of preparing the chloride, if hydrochloric acid be not too costly, the liquor is saturated with hydrochloric acid—the solution evaporated to cause the salt to crystallize, and then, finally, the crude sal ammoniac is purified by sublimation.

Before treatment with the acid, the liquor is frequently distilled.

This is generally effected in a wrought-iron boiler, the liquors passing into a modification of the Coffey's still, by which the solution of ammonia is obtained freer from tar and more concentrated.

The Saturation of the Ammoniacal Liquor with the acid is generally effected by allowing the acid to flow, from a large leaden vessel in which it is held, into an underground tank (fig. 27) containing the liquor, which is furnished with an exit tube passing into a chimney, to carry off the sulphurated hydrogen and other offensive gases which are disengaged.

Or, in other works, the gas liquor is put into large tuns, and the acid lifted in gutapercha carboys by cranes, thrown into the liquor and stirred with it by means of an agitator; the offensive gases being in this case made to traverse the fire of the steam-engine.

Sometimes the vapors produced in the distillation of the crude gas liquor are passed in at the lower extremity of a column filled with coke, down which the acid trickles.

The Evaporation of the crude Saline Solution is generally performed in square or rectangular cast-iron vats, capable of holding from 800 to 1,500 gallons. They are encaised in brickwork, the heat being applied by fire, the flue of which takes a sinuous course beneath the lining of brickwork on which the pan rests, as shown in fig. 28.

When the liquor is evaporated to a specific gravity of 1.25, it is transferred to the crystallizing pans; but during the processes of concentration a considerable quantity of tar separates on the surface, which must be removed, from time to time, by skimming, since it seriously impedes evaporation.

The crystallization, which takes place on cooling, is performed in circular tubs, from 7 to 8 feet wide, and 2 to 3 deep, which are generally imbedded entirely or partially in the ground. To prevent the formation of large crystals, which would be inconvenient in the subsequent process of sublimation, the liquor is agitated from time to time. The crude mass obtained, which is contaminated with tarry matter, free acid and water, is next dried, by gently heating it on a cast-iron plate under a dome. The grayish-white mass remaining is now ready to be transferred to the sublimers.

The method of sublimation generally adopted in this country consists in heating down into the metal pots, shown in fig. 29, the charge of dry coarsely crystallized sal ammoniac. These pots are heated from below and by flues round the sides. The body of the subliming vessel is of cast-iron, and the lid usually of lead, or, less frequently, iron. There is a small hole at the top, to permit the escape of steam; and great attention is requisite in the management of the heat, for if it be applied too rapidly a large quantity of sal ammoniac
AMMONIUM, CHLORIDE OF.

is carried off with the steam, or even the whole apparatus may be blown up; whilst, if the temperature be too low, the cake of sal ammoniac is apt to be soft and yellow.

The sublimation is never continued until the whole of the salt has been volatilized, since the heat required would decompose the carbonaceous impurities, and they, emitting volatile oily hydrocarbons, diminish the purity of the product. In consequence of this incomplete sublimation, a conical mass (shown in fig. 29) is left behind, called the "yolk." After cooling, the dome of the pot is taken off, and the attached cake carefully removed. This cake, which is from 3 to 5 inches thick, is nearly pure, only requiring a little scraping, where it was in contact with the dome, to fit it for the market.

Modifications of the Process.—If, as is often the case, sulphuric acid is cheaper or more accessible than hydrochloric, the gas liquor is neutralized with sulphuric acid, and then the sulphate of ammonia thus obtained is sublimed with common salt, (chloride of sodium,) and thus converted into sal ammoniac.

\[ \text{NH}_4\text{SO}_3 + \text{NaCl} \rightarrow \text{NH}_4\text{Cl} + \text{NaSO}_4 \]

Mr. Croll has taken out a patent for converting crude ammonia into the chloride, by passing the vapors evolved in the first distillation through the crude chloride of manganese, obtained, as a byproduct in the preparation of chlorine, for the manufacture of chloride of lime; crude chloride of iron may be used in the same way.
Mr. Laming patented in July, 1843, the substitution of a solution of chloride of calcium for treating the crude gas liquor, instead of the mineral acids. Mr. Hills, August, 1846, proposed chloride of magnesium for use in the same way; and several other patents have been taken out by both these gentlemen, for the use of various salts in this way.

**Manufacture of Sal Ammonius from Guano.**—Mr. Young took out a patent, November 11th, 1841, in which he describes his method of obtaining ammonia and its salts from guano. He fills a retort, placed vertically, with a mixture of two parts by weight of guano, and one part by weight of hydrate of lime. These substances are thoroughly mixed by giving a reciprocating motion to the agitator placed in the retort; a moderate degree of heat is then applied, which is gradually increased until the bottom of the retort becomes red-hot. The ammoniacal gas thus given off is absorbed by water in a condenser, whilst other gases, which are given off at the same time, being insoluble in water, pass off. Solutions of carbonate, bicarbonate, or sesquicarbonate of ammonia are produced, by filling the condenser with a solution of ammonia, and passing carbonic acid through it. A solution of chloride of ammonium or sulphate of ammonia, is obtained by filling the condenser with diluted hydrochloric or sulphuric acid, and passing the ammonia through it as it issues from the retort.

Dr. Wilton Turner obtained a patent, March 11th, 1841, for obtaining salts of ammonia from guano. The following is his method of obtaining chloride of ammonium in conjunction with cyanogen compounds:—The guano is subjected to destructive distillation in close vessels, at a low red heat during the greater part of the operation; but this temperature is increased towards the end. The products of distillation are collected in a series of Woollf’s bottles, by means of which the gases evolved during the operation may be made to pass two or three times through water, before escaping into the air. These products consist of carbonate of ammonia, hydrocyanic acid, and carburetted hydrogen, the first two of which are rapidly absorbed by the water, with the formation of a strong solution of cyanide of ammonium and carbonate of ammonia. After the ammoniacal solution has been removed from the Woollf’s apparatus, a solution of protochloride of iron is added to it, in such quantities as will yield sufficient iron to convert the latter into Prussian blue, which is formed on the addition of hydrochloric acid in sufficient quantity to neutralize the free ammonia; the precipitate thus formed is now allowed to subside, and is carefully separated from the solution, and by being boiled with a solution of potash or soda, will yield the ferro-cyanide of the alkali, which is obtained by crystallizing in the usual way. The solution (after the removal of the precipitate) should be freed from any excess of free acid, by evaporation, and then, the iron, which is added as the protochloride, is precipitated as the ferric hydroxide, by the addition of ammoniacal liquor, which, acting on the oxide of iron will be precipitated, and a neutral solution of ammonia obtained. When the precipitated oxide and cyanide of iron have subsided, the solution of chloride of ammonium is drawn off by a siphon, and the sal ammoniac obtained from it by the usual processes; the oxide of iron is added to the ammoniacal solution next operated upon.

If sulphate of iron and sulphuric acid are used, sulphate of ammonia is the ammoniacal salt produced, the chemical changes and operations being similar to the above.

Since the greater part of the nitrogen present in guano exists in the state of ammoniacal salts, which are decomposed at a red heat, nearly the whole of the ammonia which it is capable of yielding is obtained by this method; still there cannot be a doubt that the conversion of the urea, uric acid, and other nitrogenized organic bodies into ammonia, is greatly facilitated by mixing the guano with lime before heating it, as in Mr. Young’s process.

**Manufacture of Sal Ammonius from Urine.**—The urine in the urine of man and other animals is extremely liable to undergo a fermentative decomposition in the presence of the putrefying nitrogenous matters always present in this excrement, by which it is converted into carbonate of ammonia.

By treating stale urine with hydrochloric acid, sal ammoniac separates on evaporation.

**Properties.**—Chloride of ammonium (or sal ammoniac) usually occurs in commerce in fibrous masses of the form of large hemispherical cakes with a round hole in the centre, having, in fact, the shape of the domes in which it has been sublimed. By slowly evaporating its aqueous solution, the salt may occasionally be obtained in cakes nearly an inch in height; but it generally forms feathery crystals, which are composed of rows of minute octahedra, attached by their extremities. Its specific gravity is 1.45, and by heating it sublimes without undergoing fusion. It has a sharp and acid taste, and one part dissolves in 2:72 parts of hot, or in an equal weight of cold water.

It is recognized by its being completely volatile on heating, giving a white curly precipitate of silver on the addition of nitrate of silver to its aqueous solution, and by the copious evolution of ammonia on mixing it with lime, as well as the production of the yellow precipitate of the double chloride of ammonium and platinum (NH₄Cl, P₄Cl₆) on the addition of bichloride of platinum.

**Impurities.**—In the manufacture of chloride of ammonium, if the purification of the liquor be not effected before crystallizing the salt, some traces of protochloride of iron are generally present, and frequently a considerable proportion. Even when the salt is
AMMONIUM, SULPHIDES OF.

sublimed, the chloride of iron is volatilized together with the chloride of ammonium, and appears to exist in the salt in the form of a double compound (probably of FeCl + NH₄Cl), analogous to the compounds which chloride of ammonium forms with zinc and tin) 140; and this not only in the brown seams of the cake, but likewise in the colorless portion. This accounts for the observation so often made in the laboratory, that a solution of sal ammoniac, which, when recently prepared, was perfectly transparent and colorless, becomes gradually red from the peroxidation of the iron and its precipitation in the form of sesqui-oxide.

It is in consequence of the existence of the iron in the state of this double salt, that Wurtz found that chloride of ammonium containing iron in this form gave no indications of its presence by the usual re-agents until after the addition of nitric acid; and it is curious that there likewise exists a red compound of this class in which the iron exists in the state of perchloride similarly marked, in fact as N₂P₂ Cl FeCl₄.

A very simple method of removing the iron, suggested by Mr. Brewer, consists in passing a few bubbles of chlorine gas through the hot concentrated solution of the salt, by which the protochloride of iron is converted into the perchloride.

2FeCl + Cl₂ = FeCl₃

The free ammonia always present in the solution decomposes this perchloride with precipitation of sesqui-oxide, and formation of an additional quantity of sal ammoniac.

FeCl₃ + 3NH₃ = FeCl₃·3NH₃

The sesqui-oxide of iron, which is of course present in the form of a brown hydrate, is filtered off or separated by decantation, and a perfectly pure solution is obtained.

The only precaution necessary is to avoid passing more chlorine than is requisite to peroxidize the iron, since the ammonia salt itself will be decomposed with evolution of nitrogen, and the dangerously explosive body, chloride of nitrogen, may result from the union of the liberated nitrogen with chlorine.

Uses.—The most important use of sal ammoniac in the arts is in joining iron and other metals, in tinning, &c. It is also extensively used in the manufacture of ammonium, which is now largely employed in the manufacture of mordants instead of potash.- A considerable quantity is also consumed in pharmacy.

Sal ammoniac is one of those salts which possess, in a high degree, the property of producing cold whilst dissolving in water; it is, therefore, a common constituent of frigoric mixtures. See Freezing.

AMMONIUM, SULPHIDES OF. When sulphuretted hydrogen gas is passed into a solution of ammonia in excess, it is converted into the double sulphide of ammonium and hydrogen—or, as it is frequently called, the hydrosulphate of sulphide of ammonium—NH₃·HS.

This solution is extensively employed as a re-agent in the chemical laboratory, for the separation of these metals the sulphides of which are soluble in acids—viz., nickel, cobalt, manganese, zinc, and iron, which are precipitated by this re-agent in alkaline solutions.

By exposure to the air, the hydrosulphuric acid which it contains is decomposed, the hydrogen being oxidized and converted into water, whilst the liberated sulphur is dissolved by the sulphide of ammonium, forming the bisulphide, or even higher sulphide.

This solution of the polysulphide of ammonium is a valuable re-agent for dissolving the sulphides of certain metals, such as tin, antimony, and arsenic, the sulphides of which play the part of acids and form salts with the sulphide of ammonium.

By this deportment with sulphide of ammonium, these metals are separated both on the small scale in the laboratory and also on the large scale, from the sulphides of those metals—such as lead, copper, mercury, &c.—the sulphides of which are insoluble in sulphide of ammonium.

The higher sulphides, viz., the tersulphide, NH₃·S₂, and the pentasulphide, NH₃·S₅,—are bodies of purely scientific interest. They are obtained by distilling the corresponding sulphides of potassium with sal ammoniac.

All the sulphides of ammonium are soluble in water without decomposition. Ammonia combines with all the other inorganic and organic acids, the name of which is "ammoniac," but for an account of these bodies we must refer to the "Dictionary of Chemistry," as they have but few applications in the arts and manufactures.

AMORPHOUS. This term may be regarded as the opposite of crystalline. Some elements exist in both the crystalline and the amorphous states, as carbon, which is amorphous in charcoal, but crystalline in the diamond.

The peculiarities which give rise to these conditions—evidently depending upon molecular forces which have not yet been defined—present one of the most fertile fields for study in the range of modern science.

AMYGDALINE. (C₁₀ H₁₈ NO₃ + 6HO.) A peculiar substance, existing ready formed in bitter almonds, the leaves of the cherry laurel, the kernels of the plum, cherry, peach,
and the leaves and bark of *Prunus Padus* and in the young sprouts of the *P. domestica*. It is also found in the sprouts of several species of *Sorbus* such as *S. avensis*, *S. torminalis*, and others of the same order. To prepare it, the bitter almonds are subjected to strong pressure between hot plates of metal. This has the effect of removing the bland oil known in commerce as almond oil. The residue, when powdered, forms almond meal. To obtain amygdaline from the meal, the latter is extracted with boiling alcohol of 90 or 95 per cent. The tincture is to be passed through a cloth, and the residue pressed, to obtain the fluid mechanically adherent to it. The liquids will be milky, owing to the presence of some of the oil. On keeping the fluid for a few hours, it may be separated by pouring off, or by means of a funnel, and so obtained clear. The alcohol is now to be removed by distillation, the latter being continued until five-sixths have come over. The fluid in the retort, when cold, is to have the amygdaline precipitated from it by the addition of half its volume of ether. The crystals are to be pressed between folds of filtering paper, and recrystallized from concentrated boiling alcohol. As thus prepared it forms pearly scales very soluble in hot alcohol, but sparingly when cold; it is insoluble in ether, but water dissolves it readily and in large quantity. The crystals contain six atoms of water of crystallization. Most persons engaged in chemical operations have noticed, when using almond meal for the purpose of luting, that, before being moistened with water, it has little odor, and what it has is of an oily kind; but, after moistening, it soon acquires the powerful and pleasant perfume of bitter almond oil. This arises from a singular reaction taking place between the amygdaline and the vegetable albumen or emulsion. The latter merely acts as a ferment, and its elements in no way enter into the products formed. The decomposition, in fact, takes place between one equivalent of amygdaline and four equivalents of water, the product being one equivalent of bitter almond oil, two equivalents of grape sugar, and one of prussie acid. Or, represented in symbols:—

\[
\begin{align*}
C_5H_7NO_3^+ + 4H_2O &= C_6H_5O_4^- + C_6H_6N + 2C_2H_5OH^+.
\end{align*}
\]


In preparing amygdaline, some chemists add water to the residue of the distillation of the tincture, and then yeast, in order to remove the sugar present, by fermentation, previous to precipitating with ether; the process thus becomes much more complex, because it is necessary to filter the fermented liquid, and concentrate it again by evaporation, before precipitating out the amygdaline.

The proof that the decomposition which is experienced by the bitter almond cake, when digested with water, is owing to the presence of the two principles mentioned, rests upon the following considerations: If the marc, or pressed residue of the bitter almond, be treated with boiling water, the emulsion—or vegetable albumen—will become coagulated, and incapable of inducing the decomposition of the amygdaline. Moreover, if the latter be removed from the marc with hot alcohol previous to operating in the usual manner for the extraction of the essential oil, not a trace will be obtained. It is only the bitter almond which contains amygdaline; the sweet variety is, therefore, incapable of yielding the essence by fermentation. But sweet almonds resemble the bitter containing emulsion; and it is exceedingly interesting—as illustrating the truth of the explanation given above—that if a little amygdaline be added to an emulsion of sweet almonds, the bitter almond essence is immediately formed. The largest proportion of essential oil is obtained when the marc is digested, previous to distillation, with twenty times its weight of water, for a day and a night. A temperature of 100° is the most favorable for the digestion.—C. G. W.

ANCHOR. The metal employed for anchors of wrought-iron is known as "scrap iron," and for the best anchors, such as Lenox's, they also use good "Welsh mine iron."

It is not practicable, without occupying more space than can be afforded, to describe in detail the manufacture of an anchor. It does not, indeed, appear desirable that we should do so, since it is so special a form of mechanical industry, that few will consult this volume for the sake of learning to make anchors. The following will therefore suffice: The anchor smith's forge consists of a hearth of brickwork, raised about 9 inches above the ground, and generally about 7 feet square. In the centre of this is a cavity for containing the fire. A vertical brick wall is built on one side of the hearth, which supports the dome, and a low chimney to carry off the smoke. Behind this wall are placed the bellows, with which the fire is urged; the bellows being so placed that they blow to the centre of the fire. The unril and the crane by which the heavy masses of metal are moved from and to the fire are adjusted near the hearth. The Hercules, a kind of stamping machine, or the steam hammer, need not be described in this place.

To make the anchor, bars of good iron are brought together to be forged; the number varying with the size of the anchor. The forge is kept together by hoops of iron, and the whole is placed upon the properly arranged hearth, and covered up by small coals, which are thrown upon a kind of oven made of cinders. Great care and good management are required to keep this temporary oven sound during the combustion—a smith strictly
ANCHOR.

attends to this. When all is arranged, the bellows are set to work, and a blast urged on the fire; this is continued for about an hour, when a good welding heat is obtained. The mass is now brought from the fire to the anvil, and the iron welded by the hammers. One portion having been welded, the iron is returned to fire, and the operation is repeated until the whole is welded into one mass.

This will be understood by referring to the annexed figures, (fig. 30,) in which the bars for the shanks, a a, and the arms, b b, are shown, in plan and sections, as bound together, and their shapes after being welded before union; and c c represents the palm.

The different parts of the anchor being made, the arms are united to the end of the shank. This must be done with great care, as the goodness of the anchor depends entirely upon this process being effectively performed. The arms being welded on, the ring has to be formed and welded. The ring consists of several bars welded together, drawn out into a round rod, passed through a hole in the shank, bent into a circle, and the ends welded together. When all the parts are adjusted, the whole anchor is brought to a red heat, and hammered with lighter hammers than those used for welding, the object being to give a finish and evenness to the surface.

The toughest iron which can be procured should be used in the manufacture of an anchor, upon the strength of which both the security of valuable lives and much property depend.

The following drawings (fig. 31) show an anchor on the old plan, and the dissected parts of which it is composed:—
and the annexed, (fig. 32,) the patent anchor as invented by Mr. Perring, with its several parts dissected as before:—

Previously to the introduction of Lieutenant Rodger's small-palmed anchor, ships were supplied with heavy, cumbersome contrivances with long shanks, and broad palms extending half way up the flukes. So badly were they proportioned, that it was no uncommon thing for them to break in falling on the bottom, particularly if the ground was rocky. But, if once firmly imbedded in stiff holding ground, there was considerable difficulty in breaking them out. The introduction of the small palm, therefore, forms an important era in the history of anchors.

The next important introduction was Porter's anchor, with movable flukes or arms. One grand object sought to be attained here, was the prevention of fouling by the cable. It was considered, also, that as great injury was frequently occasioned by a ship grounding on her anchor, the closed upper arm would remedy the evil. It was found, however, that the anchor would not take the ground properly as at first construed, and hence the "shark's fin" upon the outside of each fluke.

Rodger's invention was for some time viewed with distrust; but, from time to time, improvements were introduced, until the patent, which gained the Exhibition prize, was brought out. On this the jurors reported as follows:—

"Many remarkable improvements have been recently made by Lieutenant Rodger, R.N., insuring a better distribution of the metal in the direction of the greatest strains. The palm of the anchor, instead of being flat, presents two inclined planes, calculated for cutting the sand or mud instead of resisting perpendicularly; and the consequence is, that these new anchors hold much better in the ground. The committee of Lloyd's—so competent to judge of every contrivance likely to preserve ships—have resolved to allow for the anchors of the ships they insure a sixth less weight if made according to the plan of Lieutenant Rodger."

The original Porter's anchor has also undergone considerable modification; and, under the name of "Trotman's anchor," has now a conspicuous place.

Another invention is that of Mitcheson's, which, in form and proportions, strongly resembles Rodger's; but the palm is that adopted in Trotman's, or Porter's anchor. It is a trifle longer in the shank than Rodger's, and has a peculiar stock, which—although original in its form—lacks originality in its design, since Rodger had previously introduced a plan for an iron stock to obviate the weakness caused by making a hole for the stock to pass through. Mr. Lenox was the inventor of an anchor which differed somewhat from the Admiralty's anchor—a modification of Rodger's,—in being shorter in the shank and thicker in the flukes, the palms being spade-shaped. Mr. J. Ayley, the Master-Attendant of Sheerness Dockyard, modified the Admiralty's anchor. Instead of the inner part of the fluke, from the crown to the pea, being rounded, as in the Admiralty plan, or squared, as in Rodger's and Mitcheson's, it is hollowed. An American anchor known as Isaae's, has a flat bar of iron from palm to palm, passing the shank elliptically on both sides; and from the end of the stock to the centre of the shank two other bars are fixed to prevent its fouling.

With the anchors thus briefly described the Admiralty ordered trials to be made at Woolwich, and at the Nore. The results of those trials—the particulars of which need not be given here—were, that Mitcheson's, Trotman's, Lenox's, and Rodger's, were selected as the best.
A competent authority, writing in the *United Service Gazette*, says:—"The general opinion deduced from the series of experiments is, that although Mitcheson's has been so successful, the stock is not at present seaworthy. Trotman's has come out of the trial very successfully, but the construction is too complicated to render it a good working anchor. When once in the ground, its holding properties are very superior; in fact, a glance at its grasp will show that it has the capabilities of an anchor of another construction one-fifth larger. There are, however, drawbacks not easily to be overcome. Its taking the ground is more precarious than with other anchors; and if a ship should part her cable, it would scarcely be possible to sweep the anchor. It is also an awkward anchor to fish and to stow. Yet there are other merits which render it, upon the whole, a most valuable invention, and no ship should go to sea without one. Of Lenox's, it is sufficient to say that it has been found equal to, and that it has gained an advantage over, Rodger's; but so strong is the professional feeling in favor of the latter, that it will ever remain a favorite. Our recommendation would be thus:—Lenox and Rodger for bowers anchors, Mitcheson for a sheet, and Trotman for a spare anchor."

The following table gives at one view the results of the experiments made by the Admiralty upon breaking the trial anchors, and the time occupied upon each experiment:—

<table>
<thead>
<tr>
<th>Anchors</th>
<th>Weight</th>
<th>Proof strain</th>
<th>First Crack</th>
<th>Broke</th>
<th>Time in Breaking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lieut. Rodger's</td>
<td>19</td>
<td>8</td>
<td>19½</td>
<td>45</td>
<td>7½</td>
</tr>
<tr>
<td>Brown and Lenox's</td>
<td>20</td>
<td>14</td>
<td>21½</td>
<td>44½</td>
<td>47</td>
</tr>
<tr>
<td>Isaac's</td>
<td>21</td>
<td>0</td>
<td>21½</td>
<td>58</td>
<td>63</td>
</tr>
<tr>
<td>Trotman's</td>
<td>21</td>
<td>1</td>
<td>21½</td>
<td>61</td>
<td>55½</td>
</tr>
<tr>
<td>Henderson's</td>
<td>20</td>
<td>3</td>
<td>21½</td>
<td>54</td>
<td>7½</td>
</tr>
<tr>
<td>Admiralty's</td>
<td>21</td>
<td>2</td>
<td>21½</td>
<td>49</td>
<td>56½</td>
</tr>
<tr>
<td>Ayleen's</td>
<td>21</td>
<td>1</td>
<td>0</td>
<td>44</td>
<td>47½</td>
</tr>
</tbody>
</table>

The history of the introduction of Lenox's anchors to the British navy was as follows:—

After sundry attempts to induce the Admiralty to give up entirely the use of hempen cable anchors, in consequence of their breaking when applied to chain cables, Mr. Lenox, in 1832, was permitted to alter some of the old anchors to such proportions and shape as would enable them to stand a proof-strain upon the machine in Woolwich Dockyard. It was found, as previously apprehended and asserted, that, from the inequality of material in the old anchors, not above one in three was successfully altered, and Mr. Lenox was ordered to supply new anchors, which were proved, and then approved of. This state of things continued until 1838, when Mr. Lenox was requested to reconsider and complete the shape and proportions of anchors for the navy, with a view to a contract being given out for the supply of such anchors to the service. Then was constructed the shape called the "Admiralty," or "Sir William Parker's Anchor," (Sir William being then Store Lord.) Mr. Lenox suggested to Sir William the doing away with every sharp edge and line in an anchor, and adopting the smooth long-oval (in the section) for the general shape of shank and arm. This was approved of by Sir William, and he brought it out as his anchor. An entire table of proportions was furnished; but that it might meet with no opposition from the influence of dockyard authority, it was sent to the officers of Portsmouth Yard for their approval. They returned it, after a few months, with some slight alterations in the proportions of some of the sizes, and recommended the construction to be on "Perring's principle" of the cushioned, or made-up crown. It was so adopted, and continued to be made by Brown and Lenox for about a year or two, when the great and unnecessary expense incurred by the plan was pointed out. It was contend that it was without any good; because, if the crown of the anchor, or any cut or weld, was made sound and perfect, the amalgamation of the grain of the iron would be complete, and assume its full power or strength, whatever way it might be put together; and the strongest form was that which exposed the least surface of iron to the welding heat, and consequently to injury. About the latter end of 1839, the subject was again opened. Mr. Lenox renewed his objections, by letter, to Sir William Parker, to "Perring's plan" of shutting-up, and the consequence was—a contract with specification, &c. &c., appeared, and an improved or modified plan of shutting-up (as it

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33
is called) was proposed by Mr. Tyler, master-smith of Portsmouth Yard, which was adopted; and Mr. Lenox's shape and proportions, (slightly altered, as before said,) came out as "Sir William Parker's," or the "Admiralty Anchor," and continued, until after the trials in 1852, with every success in actual service that a good anchor could maintain, and they were made and sold in quantities to all the world.

In the navy of England, and in nearly all foreign navies, this anchor, of which fig. 33 represents the form, was adopted. They are also largely employed in the merchant service; but these are not so nicely proportioned as the anchors made for the Government, nor are they so highly finished. Many merchant captains, however, take Rodger's anchor, and our steamers almost invariably take Porter's or Trotman's anchor.
ANCHOR.

Trotman’s Anchor is represented in fig. 34, under its various positions. Although for convenience Trotman’s anchor is, as we have already stated, largely used by the merchant steamers, we cannot but feel that the separation of the fluke from the shaft, although it may be in many cases unobjectionable, is attended with the risk that when, in an emergency, the anchor is required, the means of connection may be at fault.

Captain Hall’s anchor is a very valuable one, from the circumstance that it is capable of division, as shown in fig. 35, so that it can be taken out in boats.

There are various other shapes of anchors; but attention has been confined to those generally employed.

We are not in a position to offer any opinion upon the value of the several anchors which have been named. Having described their peculiarities, there remains but little to be said. The solidity of Lenox’s anchors—as shown in fig. 36, and again in their more recent modifications, in plan and section, with the new form of iron stock, fig. 37—has recommended them strongly, and hence their general use.

The weight of anchors for different vessels is proportioned to the tonnage. The following table shows the number of anchors now carried, and the weights of each anchor, by merchant vessels by the regulation of Lloyd’s.

<table>
<thead>
<tr>
<th>Ship’s Tonnage</th>
<th>Bower</th>
<th>Stream</th>
<th>Kedge</th>
<th>Bower, Wood Stock</th>
<th>Bower, Iron Stock</th>
<th>Steam</th>
<th>Kedge</th>
<th>Second Kedge</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2</td>
<td>1</td>
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ANGORA WOOL.

ANCHovy. (Anchois, Fr.; Acciughe, It.; Anschove, Germ.) The Clupea engraulis of Linnaeus, a small fish, resembling the sprat, common in the Mediterranean Sea. The Gorgona anchovy is considered the best. Sardines (which see) are sometimes substituted for anchovies.

ANDIRONS, or HAND-IRONS, also called Firedogs. Before the introduction of raised and close fireplaces these articles were in general use. Strutt, in 1775, says: "These mend-irons are used at this day, and are called 'cob-irons'; they stand on the hearth, where they burn wood, to lay it upon; their fronts are usually carved, with a round knob at the top; some of them are kept polished and bright: anciently many of them were embellished with a variety of ornaments."

ANEMOMETER. (ænome, wind; μέτρησις, to measure.) An instrument or machine to measure the wind, its direction and force. Three descriptions of anemometers are now usually employed:—1. Dr. Whewell's; 2, Mr. Follett Osler's; 3, Dr. Robinson's. This is not the place to describe either of those most ingenious instruments, a full account of which will be found in the "Transactions of the British Association," and of the "Royal Irish Academy."

ANEROID BAROMETER. This instrument was invented by M. Viollet, of Paris. In its latest form it consists of a cylindrical case, about 4 or 5 inches in diameter, and 23 inches deep, in which lies a thin metal box, near to, and parallel with, the curved boundary of the case, its two ends being distant about half an inch from each other. From this box the air has been partially exhausted, and the pressure of the external atmosphere on it causes it to alter its form. The accompanying figure (35) shows a section of this box. It is made of thin corrugated plates of metal, so that its elasticity is great. By means of the tube p, the air is partially exhausted, when the box takes the form shown by the dotted lines. A small quantity of gas is introduced after exhaustion, the object of which is to compensate for the varying elasticity of the metal at different temperatures. The pressure of the air on the box in ordinary instruments is between 40 and 50 lbs., and it will be easily understood that any variation in this pressure will occasion the distances between the two plates to vary, and consequently the stalk will have a free motion in or out. This is, by an ingenious contrivance, changed from a vertical motion to a motion parallel to the face of the dial, and this is converted into a rotary one by the application of a watch-chain to a small cylinder or drum. The original very slight motion is augmented by the aid of levers. This is so effectually done, that when the corrugated surfaces move through only the 250th part of an inch, the index hand on the face turns over a space of three inches. The extreme portability of this little instrument, and its comparative freedom from risk of injury, render it exceedingly useful to the traveller. Its accuracy is proved by the experiments of Professor Lloyd, who placed one under the receiver of an air-pump, and found that its indications corresponded with those of the mercurial gauge to less than 0.01 of an inch; and within ordinary variations of atmospheric pressure the coincidences are very remarkable.—Lloyd, Nichol, Dow.  

ANGELICA. (Angelique, Fr.; Angelika, Germ.) The archangelica officinalis. The dried angelica root is imported from Hamburg in casks. The tender stems, stalks, and the midribs of the leaves are made, with sugar, into a sweetmeat, (candied angelica.) The angelica root and seeds are used by rectifiers and compounders in the preparation of gin, and as an aromatic flavoring for "bitters." It is cultivated in some moist places in this country. In 1855 we imported 231 tons of angelica root.

ANGORA WOOL. (Poil de chevron d'Angora, Fr.) Called also angora and angora. The wool of the Angora goat, (Capra Angorensis,) employed in the manufacture of the shawls of Cashmere, &c. This is obtained from the long-haired goat of Angora, to which province this animal is peculiar. Lieutenant Conolly has given an account of this goat and some other varieties:—

"The country where it is found was thus described to us.—Take Angora as a centre, then Kizril Ermak (or Haly's) Chomgere, and from 8 to 10 hours' march (say 30 miles) beyond; Beyazar, and the same distance beyond, to near Nalaban; Sevrec, Hissar, Yoomoolk, Toshah, Costambool, Gereleh, and Cherkesh, from the whole of which tract the common bristly goat is excluded, and the white-haired goat alone is found." The fleece of the white Angora goat is called tiflik, (the Turkish for goats' hair,) in distinction to yen, or yapak, sheep's wool. After the goats have completed their first year, they are clipped annually, in April or May, and yield progressively, until they attain full growth, from 150 drachms to 13 oz of tiflik, (from 1 lb. to 4 lbs. English.) The hair of the tiflik goat is exported from its native districts raw, in yarn, and woven in the delicate stuffs for which Angora has been long celebrated. The last are chiefly consumed in Turkey, while the yarn
and raw material are sent to France and England. It appears that the first parcels of Angora wool were shipped from Constantinople for England in 1820, and was so little appreciated that it fetched only 10d. the pound. The exports from Constantinople then increased as follows:—

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>1835</td>
<td>3,841 bales</td>
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<tr>
<td>1836</td>
<td>5,328 bales</td>
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"Within the last two or three years, a new texture made of goats' wool has, however, been introduced both into France and this country, which calls for particular attention. This texture consists of stripes and checks expressly manufactured for ladies' dresses, and having a soft feel and silky appearance. The wool of which this article is made is chiefly the wool of the Angora goat. This wool reaches us through the Mediterraneans, and is chiefly shipped from Smyrna and Constantinople. In color it is the whitest known in the trade, and now more generally used in the manufacture of fine goods than any other. There are, however, other parts of Asiatic Turkey from which limited supplies are received; but in quality not so good as that produced in Angora. After the manufacture of shawls with goats' wool declined in France, this raw material remained neglected for a long while. About two or three years ago (1852) however, the French made another attempt, and brought out a texture for ladies' dresses in checks and stripes, which they call 'poil de chevre.' The warp is a fine spun silk, colored, and the weft Angora or Syrian white wool, which was thrown up on the surface. This article has a soft feel, and looks pretty, but in wearing is apt to out. The price of a dress of French manufacture has been from 2½, to 3½; but by adopting a cotton warp, the same article is now made in England and sold for 1½; and it is found that the cotton warp, as a mixture, suits the goats' hair best."—Southey on Colonial Sheep and Wool, London, 1852.

Angora goats' wool is used for the manufacture of plush, and for coach and decorative laces. It is also used extensively for buttons, button-holes, and the bindings of gentlemen's coats. It is equally made up into a light and fashionable cloth, suited for petticoats and overcoats, possessing the advantage of repelling wet. In France this article is now applied to the manufacture of a new kind of lace which in a great measure supersedes the costly fabrics of Valenciennes and Chantilly. The Angora wool lace is more brilliant than that made from silk, and costing only half the price, it has come into very general wear among the middle classes. The same material is also manufactured into shawls, which sell from 1½, to 1½d. each. There is much difficulty in ascertaining the quantity of Angora wool used in France, as in the returns it is mixed up with the wool of goats of Thibet, all being entered as poil de cachemire. See Mohair.

ANILINE. (C6H5 N. Syn. Phenylamine, Cynole, Benzidam, Crystalline.) This organic base having recently met with an important application in the arts in the production of a beautiful dye-color, by Mr. William H. Perkin, a short description of the methods of preparing it, and of some of its characters, becomes necessary; though for details of its most interesting relations in scientific chemistry, we must refer to the "Dictionary of Chemistry."

Preparation.—There are few bodies which admit of being prepared in a greater variety of ways—all of them interesting in tracing the chemical history of this most curious body; but we will only here describe that one which might be most advantageously carried out on a manufacturing scale. Probably the most abundant source of aniline is the basic oil of coal tar.

The oil is agitated with hydrochloric acid, which seizes upon the basic oils; after decanting the clear liquor, which contains the hydrochlorates of these oils, it is evaporated over an open fire until it begins to discengage acrid fumes, which indicate a commencement of decomposition, and then filtered to separate any adhering neutral compounds. The clear liquor is then decomposed with potash or milk of lime, which liberates the bases themselves in the form of a brown oil, consisting chiefly of a mixture of aniline (C6H5 N) and leuco or quinoleine, (C6H4N.) This mixture is submitted to distillation, and the aniline is chiefly found in that portion which passes over at or about 360° F., (182° C.) repeatedly rectification and collection of the product distilling at this temperature purify the aniline; but to complete the purification, it is well to treat the partially purified aniline once more with hydrochloric acid, to separate the bases again by an alkali, and then to rectify carefully.

The violet reaction of aniline with solution of bleaching powder enables the operator to test the distillate from time to time, to ascertain when aniline ceases to pass over, since leucol does not possess this property.—Höfmann.

Aniline may also be obtained in quantity from indigo.

When indigo-blue (see Indigo) is dissolved by the aid of heat in a strong solution of potash, and the mass, after evaporation to dryness, submitted to destructive distillation, it intumesces considerably, and aniline is liberated, which condenses in the receiver in the form of a brown oil, together with a little water and ammonia disengaged with it. The
ANILINE.

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Aniline is purified by rectification, as in the method before described. By this process the quantity of aniline obtained is about 18 to 20 per cent. of the indigo used.—Frütche.

By treatment with potash, the indigo-blue (C\textsubscript{6}H\textsubscript{3}NO\textsubscript{3}) is converted into chrysanine acid and anthranilic acid, (C\textsubscript{4}H\textsubscript{3}NO\textsubscript{4}+;) and it is this latter body which, by destructive distillation, yields carbonic acid and aniline.

\[ C_{6}H_{3}NO_{3} = C_{6}H_{3}N + 2CO_{2} \]

Nitrobenzole (which see) may be converted into aniline, either by the action of sulphuric acid hydrogen—

\[ C_{6}H_{3}NO_{3} + 6HS = C_{6}H_{3}N + 4HO + 6S \]

Nitrobenzole. Aniline.

Or, more conveniently, as has been recently shown by M. Béchamp, by the action of a basic acetate of iron.

For this purpose the following proportions have been found convenient by the writer: mix in a retort 2 lb. of iron filings, with about 2 ounces of acetic acid, then add about an equal volume of nitrobenzole. After a few minutes a brisk effervescence sets in, and the aniline distils over together with water. The reaction may require to be aided by the application of a very gentle heat; but it takes place with the greatest ease, and a very tolerably sufficient condensing arrangement should be employed. The aniline having so nearly the density of water, does not readily separate on the surface, but the addition of a few drops of ether, which dissolves in the aniline, brings it to the surface. It may then be decanted off, dried by standing for a short time over chloride of calcium, and then purified by rectification, as before described.

Properties.—Aniline is one of the organic basic derivatives of ammonia. In fact, it may be viewed as ammonia in which one equivalent of hydrogen is replaced by the compound radical Phenyl (C\textsubscript{6}H\textsubscript{5}) thus:

\[ N \{ C_{6}H_{5} \} \]

Just as phenyl is one of a series of homologous radicals, so aniline is the first of a series of homologous bases, in which the one equivalent of hydrogen is replaced by these radicals, respectively, thus:

<table>
<thead>
<tr>
<th>Homologous Radicals</th>
<th>Homologous Bases</th>
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<tr>
<td>Phenyl (-\text{C}<em>{6}H</em>{5})</td>
<td>Aniline (-\text{N})</td>
</tr>
<tr>
<td>Toluyl (-\text{C}<em>{7}H</em>{5})</td>
<td>Toluidine (-\text{N})</td>
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<tr>
<td>Xylol (-\text{C}<em>{8}H</em>{11})</td>
<td>Xyldine (-\text{N})</td>
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<tr>
<td>Cumyl (-\text{C}<em>{9}H</em>{13})</td>
<td>Cumidine (-\text{N})</td>
</tr>
<tr>
<td>Cymyl (-\text{C}<em>{10}H</em>{15})</td>
<td>Cymidine (-\text{N})</td>
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When pure, it is a colorless liquid of a high refractive power; density 1.028, and of an aromatic odor. It is slightly soluble in water, and mixes in all proportions with alcohol and ether. It boils at 360° F. (182° C.) It dissolves sulphur and phosphorus when cold, and coagulates albumen. It has no action on litmus-paper, but turns delicate vegetable colors, such as dahlia-petal infusion, blue.

Its basic characters are well developed thus: it precipitates the oxides from the salts of iron, zinc, and alumina, just like ammonia, and yields, with bichloride of platinum, a double salt similar to ammonia, the platino-chloride of aniline, (C\textsubscript{6}H\textsubscript{5} N, HCl, PtCl\textsubscript{5}), which on ignition is entirely decomposed, leaving only a residue of platinum. These characters, together with the beautiful blue color which it strikes with solution of bleaching powder, or the alkaline hypochlorites generally, are sufficient for the recognition and distinction of this body.

Salts of Aniline.—Aniline combines with acids forming a long series of salts which are in every respect analogous to the corresponding salts of ammonia. They are nearly all soluble and crystallizable, and are decomposed by the mineral alkalies with liberation of aniline. They are generally colorless, but become red by exposure to the air.

Sulphate of Aniline. (C\textsubscript{6}H\textsubscript{3}N \cdot H,O, SO\textsubscript{4}.)—This salt is employed in the manufacture of Mr. Perkin's aniline colors. It is prepared by treating aniline with dilute sulphuric acid, and evaporating gently till the salt separates. It crystallizes from boiling alcohol in the form of beautiful colorless plates of a silvery lustre, for the salt is scarcely at all soluble in cold alcohol. It is very soluble in water, but insoluble in other.

The crystals redded by exposure to the air; they can be heated to the boiling point of
ANISEED.

water without change, but when ignited they are charred with disengagement of aniline and sulphurous acid.

Oxalate of Aniline. \((C_6H_5O_3)^-\)—This is one of the best-defined salts of aniline: it separates as a crystalline mass on treating an alcoholic solution of oxalic acid with aniline. It is very soluble in hot water, much less so in cold, only slightly soluble in alcohol, and insoluble in ether.

A large number of other salts are known. The hydrochlorate, hydrobromate, hydrate, nitrate, several phosphates, citrate, tartrate, &c. &c.; but they are of purely scientific interest. The same remark applies to the various products of the decomposition of aniline, which have been so ably investigated by Fritzche, Zinlin, Hofmann, Gerhardt, and other chemists.

Application.—Several most beautiful colors for dying silk have been prepared by Mr. William H. Perkin, of Greenford Green, near Harrow, from certain salts of aniline, which are of different shades of violet, some more approaching purple, others more pink. They are now being extensively employed in dyeing silk, and are found to be far finer in tint, and more permanent, than any other known dyes of a similar color. The processes for their manufacture have been patented by Mr. Perkin. For the following short description of the method of preparing them, we are indebted to that gentleman:

"Take equivalent proportions of sulphate of aniline and bichromate of potash, dissolve them in water, mix, and allow the mixture to stand for several hours. The whole is then thrown upon a filter, and a black precipitate which has formed is washed and dried. It is then digested with coal-tar naphtha, to extract a brown resinous substance, and finally digested with alcohol to dissolve out the coloring matter, which is left behind on distilling off the spirit, as a coppery friable mass."—H. M. W.

ANISEED. \((\text{Anis}, \text{Fr.} ; \text{Anis}, \text{Germ.})\) The fruit or seed of the \(pimpinella anisum\), largely cultivated in Malta, Spain, and Germany; used in the preparation of the oil of anis, \(\text{oil of star anise, \(\text{glicium anisatum}\)}}\), and anise water. \(\text{Anise, \(\text{aqua anisii}\)}}\) It is also used in cordials. In 1855, 968 cwts. were imported. The \(\text{oil of star anise, \(\text{glicium anisatum}\)}}\) has the color and taste of the oil of anise; but it preserves its fluidity at 35-45° F. It is sometimes fraudulently substituted for \(\text{oil of anis, \(\text{oil of star anise, \(\text{glicium anisatum}\)}}\),

ANTHRACITE. \((\text{anthrac, coal.})\) A variety of coal containing a larger proportion of carbon and less bituminous matter than common coal.—\(\text{De la Beche}\).

Anthracite coal is obtained in this country, at Bideford, in Devonshire, in the Western divisions of the South Wales coal-field, and in Ireland. It is found abundantly in America. Professor H. B. Rogers's "Transactions of American Geologists" states that in the great Appalachian coal-field, extending 750 miles, with a chief breadth of 130 miles, the coal is bituminous towards the western limit, where it is level and unbroken, becoming anthracite towards the south-west, where it is disturbed. Anthracite coal is also found in the coal-fields of France, especially in the departments of Ille-et-Vilaine, the High Alps, Gard, Mayenne, and of Sarthe; about 42,571,000 kilogrammes (of 2,956 avoirdupois pounds each) are produced annually. Anthracite is also raised in Belgium.

Anthracite is not an original variety of coal, but a modification of the same beds which remain bituminous in other parts of the region. Anthracite beds, therefore, are not separate deposits in another sea, nor coal measures in another area, nor interpolations among bituminous coals, but the bituminous beds themselves, altered into a natural coke, from which the volatile bituminous oils and gases have been driven off.—\(\text{J. P. Lesley, on Coal}\).

Anthracite—now extensively used for iron-making, steam-engines, and for domestic purposes, in the United States—was, some 50 years since, regarded as incombustible refuse, and thrown away.

This peculiar and valuable fossil fuel is found in various parts of the old and new continent, as shown by the following lists, for which we are mainly indebted to the American publication, \textit{Statistics of Coal}, by Taylor.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
Location & Specific Gravity & Weight of a\tabularnewline & & cable yard in lbs.\\
\hline
\textbf{EUROPE.} & & \\
South Wales: Swansea & 1.263 & 2,181 \\
Clydach & 1.337 & 2,256 \\
Ynysgadwyn & 1.334 & 2,284 \\
Average & 1.445 & 2,278 \\
Ireland, mean & 1.445 & 2,278 \\
France: Allier & 1.380 & 2,247 \\
Tauto & 1.390 & 2,283 \\
Brassie & 1.430 & 2,213 \\
Belgium: Mons & 1.309 & 2,105 \\
Westphal & 1.303 & 2,278 \\
Prussian Saxony & 1.466 & 2,474 \\
Saxony & 1.300 & 2,193 \\
Average of Europe & & 2,281 \\
\hline
\end{tabular}
\caption{Specific Gravity and Weight of Anthracite in Various European Locations}
\end{table}
Localities of Anthracite and Anthracitous Coal, (continued.)

AMERICA.

<table>
<thead>
<tr>
<th>State</th>
<th>Localities</th>
<th>Specific Gravity</th>
<th>Weight of 1 cubic yard in lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvania</td>
<td>Lykens Valley</td>
<td>1.257</td>
<td>2,340</td>
</tr>
<tr>
<td></td>
<td>Lebanon co., gray vein</td>
<td>1.279</td>
<td>2,247</td>
</tr>
<tr>
<td></td>
<td>Schuylkill co., Lerberry Creek</td>
<td>1.472</td>
<td>2,184</td>
</tr>
<tr>
<td></td>
<td>Pottsville, Sharp Mountain</td>
<td>1.412</td>
<td>2,382</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>1.446</td>
<td>2,440</td>
</tr>
<tr>
<td></td>
<td>Salem Vein</td>
<td>1.574</td>
<td>2,349</td>
</tr>
<tr>
<td></td>
<td>Tamaqua, north vein</td>
<td>1.600</td>
<td>2,700</td>
</tr>
<tr>
<td></td>
<td>Mauch Chunk</td>
<td>1.550</td>
<td>2,615</td>
</tr>
<tr>
<td></td>
<td>Nesquehoning</td>
<td>1.358</td>
<td>2,046</td>
</tr>
<tr>
<td></td>
<td>Wilkesbarre, best</td>
<td>1.472</td>
<td>2,884</td>
</tr>
<tr>
<td></td>
<td>West Mahoney</td>
<td>1.317</td>
<td>2,213</td>
</tr>
<tr>
<td></td>
<td>Beaver Meadow</td>
<td>1.600</td>
<td>2,700</td>
</tr>
<tr>
<td></td>
<td>Girardville</td>
<td>1.600</td>
<td>2,700</td>
</tr>
<tr>
<td></td>
<td>Hazleton</td>
<td>1.350</td>
<td>2,015</td>
</tr>
<tr>
<td></td>
<td>Broad Mountain</td>
<td>1.472</td>
<td>2,884</td>
</tr>
<tr>
<td></td>
<td>Lackawanna</td>
<td>1.609</td>
<td>2,715</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>Mansfield</td>
<td>1.710</td>
<td>2,882</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>Portsmouth</td>
<td>1.810</td>
<td>3,054</td>
</tr>
<tr>
<td>Average in United States</td>
<td></td>
<td></td>
<td>2,601</td>
</tr>
</tbody>
</table>

The calorific value of anthracite coal is well shown by the following results from Dr. Fyle's experiments to compare Scotch and English bituminous coals with anthracite, in regard to their evaporative power, in a high-pressure boiler of a 4-horse engine, having a grate with 8·15 square feet of surface; also in a wagon-shaped copper boiler, open to the air, surface 18 feet, grate 1·55.

<table>
<thead>
<tr>
<th>Kind of Fuel employed.</th>
<th>pounds burned per hour on the grate.</th>
<th>Horse power on the grate.</th>
<th>Pressure at the grate.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middlesex Scotch coal</td>
<td>8·53</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td>Scotch coal, different variety from preceding.</td>
<td>106</td>
<td>5</td>
<td>170</td>
</tr>
<tr>
<td>Scotch coal, from near Edinburgh</td>
<td>8·44</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>English bituminous coal</td>
<td>8·24</td>
<td>4</td>
<td>50</td>
</tr>
</tbody>
</table>

Space will not admit of our entering fully into the question of the evaporative power of anthracite; but its advantages under certain conditions are fully established.

In this country anthracite coal is used in the manufacture of iron in the following furnaces:

- **Blast Furnaces making Iron from Anthracite.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Glamorganshire.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abercraf, Abernant, and Dewey.</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Banwen</td>
<td>Out of blast</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Onllwyn or Brin</td>
<td>L. Llewellyn</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Venall</td>
<td>Abercraf Iron Company</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Ystalyfira</td>
<td>Ystalyfira Iron Company</td>
<td>10</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Brecknockshire.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Abercraf</td>
<td>T. Walters</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Ystalyfira</td>
<td>Ystalyfira Iron Company</td>
<td>7</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Carmarthenshire.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bryn Ammon</td>
<td>L. Llewellyn</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Gwendraeth</td>
<td>T. Watney &amp; Co.</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Tyth Baren</td>
<td>K. H. Thomas</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pembroke.</td>
<td>Pembroke Iron and Coal Co.</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Total furnaces in blast in anthracite districts in 1857: - - - 19
Antelope Horn.

Professor W. R. Johnson, of Pennsylvania College, informs us that fourteen furnaces using anthracite for the production of iron were in use in the United States.

In the anthracite districts of South Wales, the produce was, in—

1855 - - - - 997,500 tons.
1856 - - - - 965,500 "
1857 - - - - 1,485,000 "

The following table shows the progress of production in America of anthracite from 1840 to 1857, inclusive, from Schuylkill, Lehigh, and Wyoming:—

<table>
<thead>
<tr>
<th>Year</th>
<th>Tons.</th>
<th>Increase per Year.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1840</td>
<td>864,834</td>
<td>45,982</td>
</tr>
<tr>
<td>1841</td>
<td>950,973</td>
<td>86,139</td>
</tr>
<tr>
<td>1842</td>
<td>1,108,418</td>
<td>157,445</td>
</tr>
<tr>
<td>1843</td>
<td>1,293,598</td>
<td>155,180</td>
</tr>
<tr>
<td>1844</td>
<td>1,630,850</td>
<td>367,252</td>
</tr>
<tr>
<td>1845</td>
<td>2,013,013</td>
<td>382,163</td>
</tr>
<tr>
<td>1846</td>
<td>2,344,005</td>
<td>350,992</td>
</tr>
<tr>
<td>1847</td>
<td>2,883,500</td>
<td>558,203</td>
</tr>
<tr>
<td>1848</td>
<td>3,089,338</td>
<td>206,838</td>
</tr>
<tr>
<td>1849</td>
<td>3,217,641</td>
<td>128,303</td>
</tr>
<tr>
<td>1850</td>
<td>3,321,136</td>
<td>103,495</td>
</tr>
<tr>
<td>1851</td>
<td>4,329,330</td>
<td>1,008,294</td>
</tr>
<tr>
<td>1852</td>
<td>4,899,975</td>
<td>570,645</td>
</tr>
<tr>
<td>1853</td>
<td>5,077,144</td>
<td>197,169</td>
</tr>
<tr>
<td>1854</td>
<td>5,831,834</td>
<td>734,690</td>
</tr>
<tr>
<td>1855</td>
<td>6,486,097</td>
<td>654,263</td>
</tr>
<tr>
<td>1856</td>
<td>6,751,542</td>
<td>265,445</td>
</tr>
<tr>
<td>1857</td>
<td>6,431,379</td>
<td>320,163 decrease.</td>
</tr>
</tbody>
</table>

Pottsville Miners’ Journal.

A steady increase is thus shown in the production of American anthracite, excepting during the last year. This decrease may be readily accounted for by the general depression of the iron and other manufactures.

The annual consumption of anthracite in the United States was thus stated in the Science of New York Exhibition:—

<table>
<thead>
<tr>
<th>Year</th>
<th>Tons.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1820</td>
<td>-</td>
</tr>
<tr>
<td>1825</td>
<td>-</td>
</tr>
<tr>
<td>1830</td>
<td>-</td>
</tr>
<tr>
<td>1835</td>
<td>-</td>
</tr>
<tr>
<td>1840</td>
<td>-</td>
</tr>
<tr>
<td>1845</td>
<td>-</td>
</tr>
<tr>
<td>1850</td>
<td>-</td>
</tr>
<tr>
<td>1853</td>
<td>-</td>
</tr>
</tbody>
</table>

The quantity consumed in 1856 is stated to have been 7,900,000 tons.

Antelope Horn is used occasionally for ornamental knife handles. See Horn.

Antichlore. A term employed by bleachers to the means of obviating the pernicious after-effects of chlorine upon the pulp of paper, or stuffs, which have been bleached therewith. Manufacturers have been in the habit of using sulphite of soda, whose action upon the adhering bleaching salt, which cannot be removed by washing, gives rise to the formation of sulphate and hydro sulphate of soda and chloride of sodium. Chloride of tin has been recommended by some chemists for this purpose.

Anti-Attrition, or, Anti-friction Composition. Various preparations have been, from time to time, introduced for the purpose of removing, as much as possible, the friction of machinery. Black lead, or plumage, mixed with a tenacious grease, has been much employed. Peroxide of iron, finely divided hematite, &c., have also been used.

A composition employed at Munich is reported to have been used with success and economy to diminish friction of machinery. It consists of ten and a half parts of pure hogs’ lard, fused with two parts of finely pulverized and sifted plumage. The lard is first to be melted over a moderate fire, then a handful of the plumage thrown in, and the materials stirred with a wooden spoon until the mixture is perfect; the rest of the plumage is then to be added, and again to be stirred until the substance is of uniform composition; the vessel is then to be removed from the fire, the motion being continued until the mixture is
ANTIMONY.

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quite cold. The composition, in its cold state, was applied to the pivots, the teeth of wheels, &c., by a brush, and seldom more than once in 24 hours.*

It was found that this composition replaced the oil, tallow, and tar, in certain iron works with economy, saving about \( \frac{1}{2} \) of the cost of these articles.

ANTI-FRICTION METAL. Tin and pewter are commonly employed as anti-friction metals for the bearings of locomotive engines.

Babbit's metal is prepared by taking about fifty parts of tin, five of antimony, and one of copper.

Tin or pewter, used alone, owing to its softness, spreads out and escapes under the superincumbent weight of the locomotive, or other heavy machinery. It is usual, therefore, to add antimony, for the purpose of giving these metals hardness. Fenton's Anti-friction metal is much employed, is a mixture of tin, copper, and spelter. Its advantages are stated to be cheapness in first cost, low specific gravity, being 20 per cent. lighter than gun metal; and being of a more unctuous or soapy character than gun metal, less greasy or oil is required.

The softer metal is often supported by brasses cast of the required form, the tin alloy being cast upon them. The brasses, or bearings, being properly tinned, and an exact model of the axle having been turned, the parts are heated, put together in their relative positions, saturated with plastic clay, and the fluid anti-friction metal poured in, which then becomes of the required form, and effectually solders the brass.

The following compositions are recommended to railway engineers as having been employed for several years in Belgium:—In these cases where the objects are notch exposed to friction, 20 parts of copper, 4 of tin, 0.5 of antimony, and 0.25 of lead. For objects which are intended to resist violent shocks, 20 parts of copper, 6 of zinc, and 1 of tin. For those which are exposed to heat, 17 parts of copper, 1 of zinc, 0.5 of tin, and 0.25 of lead. The copper is added to the fused mass containing the other metals.

ANTIMONY occurs with numerous ores of lead and silver, of nickel, &c., but the most important ore of antimony is the sulphur, (Sillimanite, or Gray Antimony,) which forms the chief and most common source of the antimony of commerce, and of the greater number of the pharmaceutical preparations of that metal. Antimony is not at present produced in this country, but in the last century it was mined extensively.

The most celebrated localities of this ore are Falsebones, Schemnitz, and Kremnitz, in Hungary, where it occurs in diverging prisms several inches long. It is also found in the Hartz, at Andraesberg, in Hungary, in Cornwall, at the old Trewheta mine, and abundantly in Bohemia.

This ore was called by the ancients \( \pi \alpha \tau \mu \omicron \varphi \omicron \theta \omicron \alpha \mu \lambda \omega \nu \varphi \omicron \omicron \mu \omicron \alpha \nu \omega \nu \varepsilon \) from the use to which it was applied in increasing the apparent size of the eye, as is still practised among oriental nations, by staining the upper and under edges of the eyelids. It was also used as a hair-dye and to color the eyebrows.

It was the Lupus Metallorum of the alchemists. Crude antimony is obtained from it by simple fusion, and from this product the pure metal is extracted.

The other principal ores of antimony are the following:—

_Nature Antimony_ is a mineral of a tin-white color and streak and a metallic lustre, and sometimes contains silver, iron, and arsenic, with which last it is commonly associated. It is brittle, and possesses a specific gravity of 6.92 to 6.72. It is generally lamellar, sometimes botryoidal, or reniform. Before the blowpipe it soon melts, and continues to burn after the heat is removed; but if the heat be continued, it evaporates in white fumes, and is redeposited round the globule.

Native antimony occurs at Sahlburg in Sweden, Andraesberg in the Hartz, Allemont in Dauphiny, in Mexico, &c.

_Arsecent Antimony_ also occurs at Allemont, in the Hartz, and elsewhere, in reniform and amorphous masses, with a finely granular or a curved lamellar structure. It is composed of arsenic 62.15, antimony 37.85. It possesses a metallic lustre, and a reddish-gray or tin-white lustre. Its specific gravity is 6.2.

_Oxide of Antimony (Ceraminite)_ occurs, associated with gray antimony, (of which it is an altered form,) at Cervantes, in Spain, in Hungary, and the Auvergne. It is found in octahedral crystals, and in radiating bisterous crystals in the province of Constantin, in Algeria, (Semarmontite) also at Perneck, in Hungary. It occurs as a crust or powder, or in acicular crystals, with a greasy or earthy lustre, and of a pale yellow or nearly white color. Specific gravity = 40.8. It is composed of antimony 80.1, oxygen 19.9; but frequently it contains an admixture of iron, carbonate of lime, &c. It is soluble in muriatic acid.

_White Antimony (Valentinite)_ is the result of the alteration of gray antimony, native antimony, and other ores of that metal. It possesses a shining pearly lustre and a snow-white color, but is sometimes pinkish, or ash-gray, or brownish. It affords a white streak. It is composed of antimony 84.32, oxygen 15.68. Specific gravity = 5.96. It is found in tubular crystals in veins traversing the primary rocks at Prizbain in Bohemia, near Freyberg in Saxony, Allemont in Dauphiny, &c.

* Ann. des Mines, xi. 79.
ANTIMONY, GLASS OF.

Red Antimony (Kermesite) is a compound of oxide of antimony 39-2, and sulphide of antimony 60-8, or antimony 74-45, oxygen 5-29, and sulphur 20-19.

It occurs generally in capillary six-sided prismatic crystals of a cherry-red color, affording a brownish-red streak. It has a specific gravity of from 4-5 to 4-6.

It is feebly translucent, and possesses an adamantine lustre. It occurs at Walaczka in Hungary, Brunsdorf in Saxony, and at Allemont in Dauphiny.

At Malboeuf, in the department of Argonne, in France, the separation of the sulphide of antimony from its associated gangue is effected by means of a peculiar apparatus, (fig. 39.) The mineral is placed in large retorts, r r, of which four are set in each furnace. An aperture is left at the bottom of each of these cylinders, which corresponds with a similar opening by which they are supported. Beneath these, in the chambers c c, are placed earthen pots, f f, in which is received the melted sulphide as it descends through the openings in the cylinders. The fuel consumed on the grate consists of fir wood; and the sulphide obtained is converted into metallic antimony by roasting in a reverberatory furnace, and subsequent reduction by a mixture of 20 per cent. of powdered charcoal which has been saturated with a strong solution of the carbonate of soda.

Melted with tin, antimony has of late been used as an anti-friction alloy for railway axles, and other bearings; in metallic rings, or collars, for machinery. As this alloy is not so much heated by friction as the harder metals, less grease is consumed.

ANTIMONY, GLASS OF. This substance, according to M. Soubeiran, contains—

<table>
<thead>
<tr>
<th>Substance</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protoxide of antimony</td>
<td>0-5</td>
</tr>
<tr>
<td>Silica</td>
<td>4-5</td>
</tr>
<tr>
<td>Peroxide of iron</td>
<td>3-2</td>
</tr>
<tr>
<td>Sulphuret of antimony</td>
<td>1-9</td>
</tr>
</tbody>
</table>

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APPLE WINE. Cider. Winckler finds that the wine from apples is distinguished from the wine from grapes by the absence of bisulphate of potash and of albuminoid acid, by its containing a smaller amount of alcohol and more tannin, but especially by the presence of a characteristic acid, which he regards as lactic acid, notwithstanding that this opinion is not confirmed by the degree of solubility of its salts with oxide of zinc, lime, and magnesia. See Ch. E. vol. 1, p. 561.

AQUAFORTIS. This acid has usually been obtained by mixing common nitre with green vitriol or sulphate of iron, and distilling, or by mixing nitre and clay or siliceous matter, and distilling over the nitric acid, leaving the alkali to unite with the earthy base.

It may, however, be usefully borne in mind, that this term of aquafortis, or strong water of the old chemist, was also applied to solutions which answered their special purposes. Thus Salmon, in 1685, gives the composition of aquafortis from certain mixtures of acids, not nitric, and salts, and distinctly refers to the Pharmacopoeia for the other kind. This may be of service when applying old recipes for processes in the arts. Aquafortis did not always mean nitric acid. See Nitric Acid.

AQUAMARINE is the name given to those varieties of beryl which are of clear shades of sky-blue or greenish-blue, like the sky. It occurs in longitudinally-striated hexagonal crystals, sometimes a foot long, and is found in the Brazils, Hindostan, and Siberia. See Beryl.

AQUA REGIA. Royal water. Now called nitro-muriatic acid, or nitro-chlorohydric acid, or hypochloro-nitric acid.

Prepared under different conditions, it appears to give different results. Gay-Lussac observed that aqua regia, when heated in a water-bath, evolves a gaseous body which, dried and exposed to a frigorous mixture, separates into chlorine and a dark lemon-yellow liquid, belling at 70° F. This yellow liquid was found to contain 69-1 per cent. of chlorine; the calculated quantity for the formula NOCl, being 70-2. Gay-Lussac refutes the assertion of L. Davy and Baufrinont, that the properties of aqua regia are due to its containing a compound of chlorine, nitrogen, and oxygen, and confirms the generally received view, that its action depends upon free chlorine. From the vapor evolved in the action of aqua regia upon gold, a liquid may be condensed which is nearly of the composition NOCl, containing, however, no free chlorine.

ARABIC, GUM. Chemists have been disposed to divide gums into three varieties, to which they have given the names of Arabine, ceramine, and dextrine.
ARCHIL.

Arable, or gum Arable, exudes from several species of aceaia and pranaus; it is also found in the roots of the mallow, confrey, and some other plants. Gum Arable never crystallizes, is transparent, and has a vitreous fracture. It dissolves in water in all proportions, forming mucilage. Its chemical composition is expressed by the formula, C₉H₁₀O₆.

ARCHIL. As this dictionary is not intended to include articles connected with engineering or architecture, it would be out of place to describe the conditions required to ensure the stability of the arch, which is manifestly one of great importance to the practical builder. (For the theory of the equilibrium of the arch, Gwilt's treatise on the subject should be consulted, or the article Arch, "Encyclopaedia Britannica").

ARCHIL. (Oreille, Fr.; Oreille, Germ.; Orcello, Ital.) The name of archil is given to a coloring matter obtained, by the simultaneous action of the air, moisture, and an ammoniacal liquor, from many of the lichens, the most esteemed being the lichen rocella. It appears in commerce in three forms: 1. As a pasty matter called archil; 2, as a mass of a drier character, named peris; and 3, as a reddish powder called cubebear.

The lichen from which archil is prepared is known also as the canary weed or orchilla weed. It grows in great abundance on some of the islands near the African coast, particularly in the Canaries and several of the Islands of the Archipelago. Its color is sometimes a light and sometimes a dark gray.

The chemical constitution of archil was first investigated by M. Coq, "Annales de Chimie," vol. lixxi.; and subsequently, yet more extensively, by Robiquet, "Annales de Chimie," vol. xliii., 2d series.

From the Variolaria, Robiquet obtained Oreine, by digesting the lichen in alcohol, evaporating the dryness, dissolving the extract in water, concluding the solution to the thickness of a syrup, and setting it aside to crystallize. It forms, when quite pure, colorless prisms, of a nauseous sweet taste, which fuse easily, and may be sublimed unaltered. Its formula is C₉H₁₀O₄; 5 Aq. when sublimed; when crystallized from its aqueous solution it contains 5 Aq.

If oreine be exposed to the combined action of air and ammonia, it is converted into a crimson powder orcin, which is the most important ingredient in the archil of commerce. Oreine may be obtained by digesting dried archil in strong alcohol, evaporating the solution in a water-bath to dryness, and treating it with ether as long as any thing is dissolved; it remains as a dark blood-red powder, being sparingly soluble in water or ether, but abundantly in alcohol. Its formula is C₉H₁₀NO₇.

Oreine dissolves in alkaline liquors with a magnificent purple color; with metallic oxides it forms lakes, also of rich purple of various shades. In contact with deoxidizing agents, it combines with hydrogen, as indigo does, and forms leuc-orceine, C₉H₁₀NO₇; H. When bleached by chloride, a yellow substance is formed, chlor-orceine, the formula of which is C₉H₁₀NO₇; Cl. analogous to the other.—Kane.

Dr. Schunk, by an examination of several species of Lecanora, has proved that, although under the influence of ammonia and of air, they ultimately produce oreine, these lichens do not contain oreine ready formed, but another body, Lecanorine, which, under the influence of bases, acts as an acid, and is decomposed into oreine, and carbonic acid. If lecanoric acid be dissolved in boiling alcohol, it unites with ether, forming lecanoric ether, which crystallizes beautifully in small scales, in the rocella tinctoria and the evernia prunastri, erythric acid is found. By the oxidation of this acid, amarantirine or erythrine bitter is formed. Those substances have been carefully examined by Schunk, Stenhouse, and Kane. The chemical history of these and some other compounds is of great interest; but as they do not bear directly upon the manufacture of archil, or its use in dyeing, further space cannot be devoted to their consideration.

Kane found archil and lecanorine of commerce to contain two classes of coloring matters, as already stated, oreine and orciné, derived from it. Beyond these there were two bodies, one containing nitrogen, amorantirine, and the other destitute of nitrogen, erythric acid. This latter acid is separated from the other bodies present in archil by means of ether, in which it dissolves abundantly, forming a rich crimson solution. It gives with alkalies purple liquors, and with earthy and metallic salts colored lakes.

Beyond those already named there are several other species of lichen which might be employed in producing an analogous dye, were they prepared, like the preceding, into the substance called archil. Hellot gives the following method for discovering if they possess this property:—A little of the plant is to be put into a glass vessel; it is to be moistened with ammonia and lime-water in equal parts; a little murirate of ammonia (sal ammoniac) is added, and the small vessel is corked. If the plant be of a nature to afford a red dye, after three or four days the small portion of liquid which will run off on inclining the vessel, now opened, will be tinged of a crimson red, and the plant itself will have assumed this color. If the liquor or the plant does not take this color, nothing need be hoped for; and it is useless to attempt its preparation on the great scale. Lewis says, however, that he has tested in this way a great many mosses, and that most of them afforded him a yellow or reddish colored color; but confine require: that he obtained from only a small number a liquor of a deep red, which communicated to cloth merely a yellowish-red color.
AREOMETER.

To prepare archil, the lichens employed are ground up with water to a uniform pulp, and this is then mixed with as much water as will make the whole fluid; ammoniacal liquors from gas or from ivory-black works, or slate urine, are from time to time added, and the mass frequently stirred so as to promote the action of the air. The oreine or erythrine which exists in the lichen absorbs oxygen and nitrogen, and forms oreine. The roccelline absorbs oxygen and forms erythrolitic acid; these being kept in solution by the ammonia, the whole liquid becomes of an intense purple, and constitutes ordinary archil.—Kane.

These lichens are gathered by men whose whole time is thus occupied; they scrape them from the rocks with a peculiarly shaped knife. They prefer collecting the oreille in rainy weather, when they are more easily detached from the rocks. They gather about 2 kilogrammes a day, or about 4 j pounds. When they take their lichens to the makers of archil or ilmen for the purpose of selling them, they submit a sample to a test, for the purpose of estimating their quality. To this end they put a little in a glass containing some urine, with a small quantity of lime. As the lichens very rapidly pass into fermentation if kept in a damp state, and thus lose much of their titriential power, great care is taken in drying them; when dry they may be preserved without injury for some time.

AREOMETER. An instrument to measure the densities of liquids. (See Alcounometer.) The principle will be well understood by remembering that any solid body will sink further in a light liquid than in a heavy one. The areometer is usually a glass tube, having a small glass bulb loaded with either shot or quicksilver, so as to set the tube upright in any fluid in which it will swim. Within the tube is placed a graduated scale: we will suppose the tube placed in distilled water, and the line cut by the surface of the fluid to be marked; that it is then removed and placed in strong alcohol—the tube will sink much lower in this, and consequently we shall have two extremities of an arbitrary scale, on which we can mark any intermediate degrees.

ARNATTO, or ARNOTTO. See Annotto, vol. I. Arnatto was considered to contain two distinct coloring matters, a yellow and red, till it was shown by M. Presser that one is the oxide of the other, and that they may be obtained by adding a salt of lead to a solution of arnatto, which precipitates the coloring matter. The lead is separated by sulphurised hydrogen; and the substance being filtered and evaporated, the coloring matter is deposited in small crystals of a yellow-white color. These crystals consist of belzine; they become yellow by exposure to the air, but if they are dissolved in water they undergo no change. When ammonia is added to belzine, with free contact of air, there is formed a fine deep red color, like arnatto, and a new substance, called belzine, is produced, which does not crystallize, but may be obtained as a red powder; this is colored blue by sulphuric acid, and combines with alkalies, and is belzine with addition of oxygen. When arnatto, in the form of paste, is mixed from time to time with stale urine, it appears probable that the improvement consists in the formation of belzine from the belzine by the ammonia of the urine. It has hence been suggested that, to improve the color of arnatto, it might be mixed with a little ammonia, and subsequently exposed to the air, previously to its being used for dyeing.

A solution of arnatto and potash in water is sold under the name of Scott's Nankin Dye.

ARROBA (of wine). A Spanish measure, equal to 3.5517 gallons.

ARROW ROOT. In commerce, the term arrow root is frequently used generically to indicate a starch or feulga, as Portland arrow root, a white amylaceous powder, prepared in the Isle of Portland, from the Arum vulgare, the common Cuckoo-pint, called also Weltrodo, and Lords and Ladies.

East India arrow root, prepared from the Curaumo angustifolia.

Brazilian arrow root, the feulga of Jatropha manihot.

English arrow root, the starch of the potato. Toda arrow root, the feulga of Toccus oceaniae, which is imported into London and sold as "arrow root prepared by the native converts at the missionary stations in the South Sea Islands."

ARSENIC, derived from the Greek ἀρσενίκη, masculine, applied to orpiment on account of its poten powers. This metal occurs native in veins, in crystalline rocks, and the older schists; it is found in the state of oxide, and also combined with sulphur under the improper name of yellow and red arsenic, or orpiment and realgar. Arsenic is associated with a great many metallic ores; but it is chiefly extracted in this country from those of tin, by roasting, in which case the white oxide of arsenic, or, more correctly, the arsenious acid is obtained. On the Continent, arsenical cobalt is the chief source of arsenic.

The following are the principal ores of arsenic:

Native Arsenic.—The most common form of native arsenic is reniform and stalactitic masses, often mammillated, and splitting off in thin successive layers, like those of a shell. It possesses a somewhat metallic lustre, and a tin-white color and streak, which soon tarnishes to a dark gray. Its specific gravity is 5.93. Before the blow-pipe it gives out an
ARSENIC ACID.

arsenious odor, and volatilizes in white fumes. It is found in the Hartz, in Andreasberg, at the silver mines of Freiberg, in Chili, the Asturias, &c.

White Arsenic, or Arsenious Acid, (Arsenolite,) is often formed by the decomposition of other arsenical ores, and is composed of arsenic 65-76 and oxygen 24-24. It occurs either in minute radiating capillary crystals and crusts investing other substances, or in a stalactitic or botryoidal form. Before the blow-pipe it volatilizes in white fumes; in the inner flame it blackens and gives out an allaceous odor; its specific gravity is 3-06. It is white, sometimes with a yellowish or reddish tinge, and has a silky or vitreous lustre. It possesses an astringent, sweetish taste.—H. W. B.

Redgar, (anciently called Sandaraco,) red orpiment, or ruby sulphur, is a sulphide of arsenic, having a composition, sulphur 29-91, arsenic 70-09. It occurs in Hungary, Saxony, and Switzerland.

Orpiment, (a corruption of its Latin name, aurigmentum—golden paint,) yellow sulphide of arsenic: its composition is, sulphur 39, arsenic 61. Burns with a blue flame on charcoal, and emits fumes of sulphur and arsenic. Dissolves in nitric or aqua regia acid and ammonia.

Both realgar and orpiment are artificially prepared and used as pigments. See those articles.

Arsenic is a brittle metal, of an iron-gray color, with a good deal of brilliancy. It may be prepared by triturating arsénious acid, or the white arsenic of commerce, with black flux, (charcoal and carbonate of potash,) and subliming in a tube. If arsenical pyrites are ignited in close tubes, metallic arsenic sublimes, and sulphur of iron remains. This metal, when exposed in the air, gradually absorbs oxygen, and falls into a gray powder, (suboxide.) This is sold on the Continent as fly powder.

To prepare arsenic on a larger scale, mispickel, or the other ores employed, are pounded; some pieces of old iron are mixed with the ore, to retain the combined sulphur, and the mixture placed in retorts between four and five feet in length, to which receivers are adapted. The retorts are moderately heated by a fire placed beneath them; the ores are decomposed, and metallic arsenic is sublimed and condensed in the receivers. The arsenic obtained in this way is purified by a second distillation with a little charcoal.

Arsenic is used in small quantities in the preparation of several alloys; it is employed in the manufacture of opal glass; also is much used in the manufacture of shot, to which it imparts a certain degree of hardness; and, by preventing the distortion of the falling drops of metal, and thus securing regular globules, the manufacture is greatly facilitated.

ARSENIOUS ACID, White Arsenic, Flowers of Arsenic.—This is the white arsenic of commerce, usually called Arsenic. It is obtained in this country from the arsenical ores of iron, tin, &c., and on the Continent from those of cobalt and nickel. It is prepared by heating the ores containing arsenic on the sole of a reverberatory furnace, through which a current of air, after passing through the grate, is allowed to play. The following ores are the more remarkable of this class,—the quantity of arsenic in 100 grains is given in each case:—

<table>
<thead>
<tr>
<th>Arsenic</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mispickel, or arsenical iron</td>
<td>49-88</td>
</tr>
<tr>
<td>Lélépine, arsenical pyrites</td>
<td>65-88</td>
</tr>
<tr>
<td>Kupfernickel, arsenical nickel</td>
<td>54-73</td>
</tr>
<tr>
<td>Raunmelsbergerite, white arsenical nickel</td>
<td>72-64</td>
</tr>
<tr>
<td>Sandtine, tin-white cobalt</td>
<td>74-22</td>
</tr>
<tr>
<td>Safflorite, arsenical cobalt</td>
<td>70-27</td>
</tr>
</tbody>
</table>

In the roasting of tin ores, a considerable quantity of arsenious acid is collected in the fumes leading from the furnaces in which this process is effected.

White arsenic is extensively used in the preparation of various pigments, as the bialphide, or realgar, the termalaphide, or orpiment, and also in the mineral greens used by paper-stainers. It is employed in glass and porcelain manufacture. Considerable discussion has arisen from a statement made by Mr. A. S. Taylor, that the arsenic employed in paper-hangings was removed at the ordinary temperatures of our rooms, and that many injurious effects had resulted from the use of such paper. Although, under some circumstances, it is possible that portions of the arsenic may escape as dust from the wall of a room, experience appears against its exerting any injurious effects. Even the men employed in burning-houses, where they are necessarily exposed to the escaping oxide, do not appear to suffer in health. The following letter, published by Mr. Alfred E. Fletcher, is much to the point:—

"The color principally referred to is the acetate-arsenate of copper, commercially known as emerald green. The chief advantage which this color possesses over other of a similar tint is that, besides having greater brilliancy, it is quite permanent. The color, when exposed to the air for any length of time, does not fade in tint nor lessen in intensity, which would necessarily be the case if any evaporation of its constituent parts take place, though in the smallest degree, especially as the layer of color exposed is often extremely thin."
ARSENIOUS ACID.

Were it true that such evaporation or dissemination went on, it would indeed afford just cause of alarm, when we reflect that on the walls of houses in this country are displayed some hundred millions of square yards of paper, most of which carries on its surface a portion of arsenical coloring matter; our books are bound with paper and cloth so colored, cottons and silks, woollen fabrics and leather, are alike loaded with it. Now, it is stated that in a medical work an instance is noted in which injury has been received by those living in rooms decorated with these colors: surely, were the proximity of such materials injurious, it would not be necessary to search in recondite books for the registry of isolated cases. The fact of the large extent to which such materials have always been employed is a sufficient proof that there is no danger attending their use; moreover, workmen who have been daily employed for many years in manufacturing large quantities of these colors, under the necessity of constantly handling them, are in the regular enjoyment of perfect health, though exposed also to the general influences of a chemical factory. Let blame be laid at the right door, and let the public be assured that it is not the looking at cheerful walls, the fingering of brightly ornamented books, nor the wearing of tastefully colored clothing, that will hurt them, but the dwelling in ill-ventilated rooms."

Arsenic Poisoning by.—This poisoning is so commonly the cause of death, by accident and by design, that it is important to name an antidote which has been employed with very great success.

This is the hydrated peroxide of iron. This preparation has no action on the system, and it may therefore be administered as largely and as quickly as possible. The following statement will render the action of this hydrated salt intelligible. When hydrated peroxide of iron is mixed in a thin paste with the solution of arsenious acid, this disappears, being changed into arsenic acid, (a far less active oxide,) and the iron into protoxide 2 FeO, and AsO, producing 4 FeO + AsO, The hydrated peroxide of iron may be made in a few minutes by adding carbonate of soda to any salt of the red oxide of iron, (permanganate, muriate, acetate, &c.) It need not be washed, as the liquor contains only a salt of soda, which would be, if not beneficial, certainly not injurious.—Kane.

Detection of Arsenic in Cases of Poisoning.

Arsenious acid, which is almost always the form in which the arsenic has entered the system, possesses the power of preventing the putrefaction of animal substances; and hence the bodies of persons that have been poisoned by it do not readily putrefy. The arsenious acid combines with the fatty and albuminous tissues to form solid compounds, which are not susceptible of alteration under ordinary circumstances. It hence has frequently occurred that the bodies of persons poisoned by arsenic have been found, long after death, scarcely if at all decomposed; and even where the general mass of the body had completely disappeared, the stomach and intestines had remained preserved by the arsenious acid which had combined with them, and by its detection the crimes committed many years before have been brought to light and punished.—Kane.

The presence of arsenic may be determined by one of the following methods:

1. Portions of the contents of the stomach or bowels being gently heated in a glass tube, open at both ends, the arsenic, if in any quantity, will be sublimed, and collected as minute brilliant octahedrons.

2. Or by the presence of organic matter; if the ignition is effected in a tube closed at one end, metallic arsenic sublimes, forming a steel-gray coat, and emitting a strong smell of garlic.

3. Arsenious Nitrate of Silver produces a canary-yellow precipitate from a solution of arsenious acid, (arsenate of silver.) The phosphide of soda produces a yellow precipitate of tribasic phosphate of silver, which exactly resembles the arsenite. The phosphide is, however, the more soluble in ammonia, and when heated gives no volatile product; while the arsenic is decomposed with white arsenic and oxygen, leaving metallic silver behind.

4. Arsenious Sulphate of Copper produces a fine apple-green precipitate, which is dissolved in an excess of either acid or ammonia. It is, however, uncertain, unless the precipitate be dried and reduced.

5. The Reduction Test.—Any portion of the suspected matter, being dried, is mixed with equal parts of cyanide of potassium and carbonate of potash, both dry. This mixture is to be introduced into a tube terminating in a bulb, to which heat is applied, when metallic arsenic sublimes.

6. Marsh's Test.—This is one of the most delicate and useful of tests for this poison, and when performed with due care there is little liability to error. The liquid contents of the stomach, or any solution obtained by boiling the contents, is freed as much as possible from animal matter by any of the well-known methods for doing so. This fluid is then rendered moderately acid by sulphuric acid, and introduced into a bottle properly arranged.

Fig. 40 is the best form for Marsh's apparatus;—a is a bottle capable of holding half, or, at most, a pint. Both necks are fitted with new perforated corks, which must be perfectly tight. Through one of these the funnel tube, b, is passed air-tight, and through the
ARSENIOUS ACID.

other the bent tube, which is expanded at $f$ into a bulb about an inch in diameter. This bulb serves to collect the particles of liquid which are thrown up from the contents of the bottle, and which drop again into the latter from the end of the tube. The other end of the tube is connected, by means of a cork, with tube $d$, about six inches long, which is filled with fused chloride of calcium, free from powder, destined to retain the moisture. In the opposite end of the tube $d$ is fixed, air-tight, another tube, $e$, made of glass free from lead, 12 inches long, and, at most, $\frac{1}{4}$ of an inch in internal diameter. It must be observed that the funnel tube $b$ is indispensably necessary to introduce the fluid to the pieces of perfectly pure metallic zinc already placed in the bottle. Hydrogen gas is at once formed, and if arsenic is present, in even the smallest quantity, it combines with the hydrogen, and (constituents: arsenic and hydrogen) escapes. If the gas as it issues from the jet is set on fire, no product but water is generated if the hydrogen is pure; and by holding against the flame a cold white porcelain basin, or piece of glass, or of nica, no steam is produced, and a dew is formed upon the cold surface. If arsenic be present, a deposit is obtained, which, according to the part of the flame in which the substance to receive it is placed, will be either a brown stain of metallic arsenic, or a white one of arsenious acid. If the quantity of arsenic is too small to be detected in this way, it will be well to ignite the horizontal part of the tube. All the arseniuretted hydrogen will, in passing that point, become decomposed, and deposit its arsenic. The heat will drive this forward, and a little beyond the heated portion metallic arsenic will be condensed. Several precautions are necessary to be observed; but for the details of those we must refer to works especially directed to the consideration of this subject. One source of error must, however, be alluded to. A compound of antimony and hydrogen is formed under similar circumstances; and this gas in many respects resembles the compound of arsenic and hydrogen. If the stain formed by the flame is arsenic, it will dissolve, when heated, in a drop or two of sulpho-hydrate of ammonia, and a lemon-yellow spot is left; if antimony is present, it leaves a yellow stain.

—Wölker.

7. Fleitmann's Test.—If a solution containing arsenic be mixed with a large excess of concentrated solution of potassa, and boiled with fragments of granulated zinc, arseniuretted hydrogen is evolved, and may be easily reorganized by allowing it to pass on to a piece of filter paper spotted over with solution of nitrate of silver. These spots assume a purplish-black color, even when a small quantity of arsenic is present. This experiment may be performed in a small flask, furnished with a perforated cork carrying a piece of glass tube of about $\frac{1}{4}$ inch diameter. It will be observed that this test serves to distinguish arsenic from antimony.

The following remarks on the Toxicological Discovery of Arsenic deserve attention:—

This active and easily administered poison is fortunately one of those most easily and certainly discovered; but the processes require great precaution to prevent mistaken inferences: if due care is taken, arsenic can be found after any lapse of time, as well as after the most complete putrefaction of the animal remains. The longest time by which it has been discovered by myself is eight years, which was the case of an infant; nothing but the bones of the skeleton remained, the coffin was full of earth, and large roots of a tree had grown through it. The metal was obtained from the bones, and in the earth immediately below where the stomach had existed. Many cases have occurred in my experience, where one, two, three, four, and five years have elapsed; in one case after fourteen months, where the body of a boy had been floating in a coffin full of water. The poison is given in one of three states, white arsenious acid, yellow sulphuret ("orpiment") or "realgar," red sulphuret of arsenic; and it is worthy of notice, that putrefaction will turn either white or red into yellow, but will never turn yellow into either white or red; this is owing to the hydrasulphuret of ammonia discouraged during decomposition.

Modern toxicologists have abandoned all the old processes for the detection of this poison, and have adopted one or two, which have been found more expeditious, as well as more certain. The first was proposed by Marsh, of Woolwich: it is founded upon the principle that metallic hydrogen will absorb and carry off any arsenic which may be present, as arseniuretted hydrogen; but as I prefer the principle first proposed by Reinsch, and
have always acted upon it, I shall confine my description to the processes founded upon it. The principle is this: arsenic mixed or combined with any organic matter, if boiled with pure hydrochloric acid and metallic copper, be deposited upon the copper; but as this depositing property is also possessed by mercury, antimony, bismuth, lead, and tellurium, subsequent operations are required to discriminate between the deposits. I take pieces of copper wire, about No. 13 size, and 24 inches long; these I hammer on a polished plane with a polished hammer, for half their length, (fig. 41,) and having brought the suspected materials to a state of dryness, and heated the copper blade in the pure hydrochloric acid, to prove that it contains no metal capable of depositing, I introduce a portion of the suspected matter and continue the boiling; if the copper becomes now either steel-gray, blue, or black, I remove it, and wash it free of grease in another vessel in which there is hot dilute hydrochloric acid; I now dry it, and, with a scraper with a fine edge, take off the deposit with some of the adhering copper, and repeat the boiling, washing, and scraping, so as to have four or five specimens on copper; one of these is sealed up hermetically in a tube for future production. I now take a piece of glass tube, and having heated it in the middle, draw it out, as in fig. 42, dividing it at a, each section being about 2 inches long, the wide orifices being about $\frac{3}{8}$ of an inch in diameter, and $\frac{1}{8}$ an inch long, the capillary part $\frac{4}{8}$ of an inch in diameter, and $\frac{1}{4}$ inch long; now, by putting one portion of the scrapings into one of the tubes at a, and holding it upwards over a very small flame, so that the volatile products may slowly ascend into the narrow portion of the tube, we prove the nature of the deposit: if mercury, it condenses in minute white shining globules; if lead or bismuth, it does not rise, but melts into a yellowish glass, which adheres to the copper; if tellurium, it would fall as a white amorphous powder; if antimony, it would not rise at that low temperature; but arsenic acid condenses as minute octahedral crystals, looking with the microscope like very transparent grains of sand. I make three such sublimates, one of which is sealed up like the arsenic for future production. I now cut the capillary part of another of the tubes in pieces, and boil it in a few drops (say 10) of distilled water, and when cold drop three or four drops on a plate of white porcelain, and with a glass rod drop one drop of ammoniacal sulphate of copper in it: and now to make the colours from this and the next test more conspicuous, I keep a chalk stone,计划 and cleaned, in readiness, and placing on it a bit of clean white filtering paper, I conduct the drops of copper test upon the paper, which permits the excess of copper solution to pass through into the chalk, but retains the smallest proportion of Scheele's green; the other few drops of the solution are treated the same way with the ammoniacal nitrate of silver. When I get the yellow precipitate of arsenite of silver, the papers, with these two spots, are now dried and sealed up in a tube as before, and that with the silver must be kept in the dark, or it will become black. I have still one of the tubes with the arsenical sublimate remaining; through this I direct a stream of hydro-sulphurous acid gas for a few seconds, which converts the sublimate into yellow orpiment. I have now all five tests: the metal, the acid, arsenite of copper, arsenite of silver, and yellow sulphuret; and the $\frac{1}{50000}$ of a grain of arsenic is sufficient in adroit hands to produce the whole; but all five must be present, or there is no positive proof, for many matters will cause a darkness of the copper in the absence of arsenic—sulphures even from putrefaction—but there is no sublimate in the second operation, because the sulphur burns into sulphurous acid and passes off upwards. Corn, grasses, and earth slightly darken it from some unknown cause, but produce no sublimate; so, if the solution of suspected arsenious acid is tested with the copper test while hot, it will produce a greenish deposit of oxide of copper, through the heat dissipating a little ammonia, or if the copper blade has not been deprived of grease by the diluted hydrochloric acid, the sublimed acid from the grease will precipitate copper from that test; but as much of the sulphuric acid of commerce, and nearly all such hydrochloric acid and some commercial zinc contain arsenic, nothing can excuse a toxicologist who attempts to try for arsenic if he has not previously experimented with all his reagents before he introduces the suspected matters. I should also mention that this metal is to be found in all parts of the body, but longest, and in greatest quantity, in the liver, where it is frequently found many days after it has disappeared from the intestines.—W. Herapath.

Arsenious acid of commerce is frequently adulterated with chalk or plaster of Paris. These impurities are very easily detected, and their proportions estimated. Arsenious acid is entirely volatilized by heat, consequently it is sufficient to expose a weighed quantity of the substance to a temperature of about 400° F. in a capsule or crucible. The whole of the arsenic will pass off in fumes, while the impurities will be left behind as a fixed residuum, which can, upon cooling, be weighed.

It is scarcely necessary to state that, the fumes of arsenic being very poisonous, the volatilization should be carried on under a chimney having a good draught.
ARTESIAN WELLS.

Our Imports of Arsenic were as follows:—

<table>
<thead>
<tr>
<th>Year</th>
<th>Arsenic imported (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1835</td>
<td></td>
</tr>
<tr>
<td>1836</td>
<td></td>
</tr>
</tbody>
</table>

ARTESIAN WELLS. The most remarkable example of an Artesian well is that at the abattoir of Grenelle, a suburb of the southwest of Paris, where there was a great want of water. It cost eight years of difficult labor to perforate. The geological strata round the French capital are all of the tertiary class, and constitute a basin similar, in most respects, to that upon which London stands. The surface at Grenelle consists of gravel, pebbles, and fragments of rocks, which have been deposited by the waters at some period anterior to any historical record. Below this layer of detritus, it was known to the engineer that marl and clay would be found. Underneath the marl and the clay, the boring rods had to perforate pure gravel, plastic clay, and finally chalk. No calculation from geological data could determine the thickness of this stratum of chalk, which, from its powers of resistance, might present an almost insuperable obstacle. The experience acquired in boring the wells of Elbeuf, Rouen, and Tours, was in this respect but a very imperfect guide. But, supposing this obstacle to be overcome, was the engineer sure of finding a supply of water below this mass of chalk? In the first place, the strata below the chalk possessed all the necessary conditions for producing Artesian springs, namely, successive layers of clay and gravel, or of pervious and impervious beds. M. Maine, however, relied on his former experience of the boring of the wells at Rouen, Elbeuf, and Tours, where abundant supplies of water had been found below the chalk, between similar strata of clay and gravel, and he was not disappointed.

The strata traversed in forming this celebrated well were as follows:—

<table>
<thead>
<tr>
<th>Strata</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift-sand and gravel,</td>
<td>33</td>
</tr>
<tr>
<td>Lower tertiary strata,</td>
<td>115</td>
</tr>
<tr>
<td>Chalk with flints,</td>
<td>1,149</td>
</tr>
<tr>
<td>Ditto, lower,</td>
<td>246</td>
</tr>
<tr>
<td>Calcareous sandstone, clays, and sands ending in a bed of green-colored sand,</td>
<td>256</td>
</tr>
</tbody>
</table>

The surface of the ground at the well is 102 feet above the level of the sea, and the water is capable of being carried above this to a height of 120 feet.

The French geologists consider that the sands from which the supply is obtained are either subordinate beds of the gault, or as belonging to the lower greensand. They crop out in a zone of country about 100 miles eastward of Paris, and range along the segment of a circle, of which Paris is the centre, from between Sancerre and Auxerre, passing near to Troyes, thence to St. Dizier to St. Ménéhould. The outcrop of this formation is continued some distance further north; it is also prolonged beyond Sancerre, south-westward towards Bourges, Chatellerault, and then north-west to Saumur, Le Mans, and Alençon. But the superficial area which it occupies in these latter districts does not appear to contribute to the water supply of Paris, for the axis of elevation of Mellerault must intercept the subterranean passage of the water from the district south of that line, whilst, on the north of Paris, the antecline line of the "Pays de Bray," and some smaller faults in the Aisne, produce probably a similar stoppage with respect to the northern districts. The superficial area, therefore, within which the strata at the well of Grenelle draw their supplies of water, forms on the east of Paris a belt stretching from near Auxerre to St. Ménéhould.

The exposed surface of the water-bearing beds which supply the well of Grenelle is about 117 square miles; the subterranean area in connection with these lines of outlet may possibly be about 20,000 square miles, and the average thickness of the sands of the gis’s verts, serving in their underground range as a reservoir for the water, does not probably exceed 30 or 40 feet.—Protestant on the Water-bearing Strata of London.

As the cost of these wells is an important consideration, the following statement from the "Water-bearing Strata of London" is of much value:—

"M. Dégousée has recently informed me of his having contracted to bore an Artesian well at Rouen to the depth of 1,080 feet, (through the lower cretaceous and eolithic series,) for £2,000, expenses of every kind to be defrayed by him. M. Dégousée has constructed three Artesian wells in different parts of France, of about £290 to £300 each, at an expense, including tubes and all expenses, of from £600 to £1,000. The Calais well offers a very near counterpart of the deposits which occur beneath London, but the difficulties of the first 240 feet much exceeded those which would be met with here, and the chalk is probably 100 to 200 feet thicker. Here and at Paris the first 1,000 feet cost less than £2,000, and at Banbury apparently not much more than £2,000."

The following Table shows the cost of several of the Artesian wells of France:—

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ARTILLERY.

Grenelle, Dept. Seine, 1,286 feet £14,500
Calais, Pas de Calais, 1,138 " 3,560
Donchery, Ardeches, 1,215 " 5,045
St. Fargeau, Yonne, 666 " 1,216
Lille, " Nord, 592 " 220
Creone, Seine and Oise, 333 " 190
Brou, " Marne, 246 " 200
Ardes, " Nord, 155 " 64
Claye, " Seine and Marne, 108 " 78
Chaville, " Oise, 65 " 15

It appears that, in England, the cost of boring is about 5s. for the first 10 feet, £2 10s. for forty feet, £5 5s. for 60 feet, £13 15s. for 100 feet, and so on in proportion. (See Sir Charles Lyell's "Principles of Geology" where the geological question is fully treated.)

ARTILLERY. One of the first inquiries of importance in connection with the construction of pieces of artillery is that of the liability to fracture in the metal. Upon this point the researches of Mr. Mallet furnish much important matter. He tells us, as the result of his investigation, that it is a law of the molecular aggregation of crystalline solids, that when their particles consolidate under the influence of heat in motion, their crystals arrange and group themselves with their principal axes in lines perpendicular to the cooling or heating surfaces of the solid; that is, in the lines of the direction of the heat-wave in motion, which is the direction of least pressure within the mass. And this is true, whether in the case of heat passing from a previously fused solid in the act of cooling and crystallizing in consolidation, or of a solid not having a crystalline structure, but capable of assuming one upon its temperature being sufficiently raised, by heat applied to its external surfaces, and so passing into it.

Cast-iron is one of those crystallizing bodies which, in consolidating, obeys, more or less perfectly, according to conditions, the above law. In castings of iron the planes of crystallization group themselves perpendicular to the surfaces of external contour. Mr. Mallet, after examining the experiments of Mr. Fairbairn—who states ("Trans. Brit. Ass.," 1833) that the grain of the metal and the physical qualities of the casting improve by some function of the number of meltings; and he fixes on the thirteenth melting as that of greatest strength—shows that the size of crystals, or coarseness of grain in castings of iron, depends, for any given "make" of iron and given mass of casting, upon the high temperature of the fluid iron above that just necessary to its fusion, which influences the time that the molten mass takes to cool down and assume the solid state.

The very lowest temperature at which iron remains liquid enough fully to fill every cavity of the mould without risk of defect is that at which a large casting, such as a heavy gun, ought to be "poured." Since the cooling of any mass depends upon the thickness of the casting, it is important that sudden changes of form and dimensions in the parts of cast-iron guns should be avoided. In the sea and land service 15-inch mortars, where, at the chamber, the thickness of metal suddenly approaches twice that of the chase, is a malconstruction full of evils.

The following statements of experiments made to determine the effect produced on the quality of the iron in guns, by slow or rapid cooling of the casting, are from the report of Major W. Wade, of the South Boston Foundry, to Colonel George Bomford, of the Ordnance Department of the United States. Three six-pounder cannon were cast at the same time from the same melting of iron. The moulds were similar, and prepared in the usual manner. That in which No. 1 was cast was heated before casting, and kept heated afterwards by a fire which surrounded it, so that the flask and mould were nearly red-hot at the time of casting; and it was kept up for three days. Nos. 2 and 3 were cast and cooled in the usual way.

At the end of the fourth day, the gun No. 1 and flask were withdrawn from the heating cylinder while all parts were yet hot. Nos. 1 and 2 were bored for 6-pounders in the usual way; No. 3 for a 12-pounder howitzer, with a 6-pounder chamber. The firing of the guns was in every respect the same. Nos. 1 and 2 were fired the same number of times with similar charges. No. 1 burst at the 27th fire, and No. 2 at the 45th. It appears, from these results, that no material effect is produced on the quality of the iron by these different modes of cooling the castings.

A very extensive series of experiments were made by the order of the United States Government, on the strength of guns cast solid or hollow. In these it was confirmed that the guns cast hollow endured a much more severe strain than those cast solid. Considerable differences were also observed, whether the casting was cooled from within or without; and Lieutenant Rodman's method of cooling from the interior is regarded as tending to prevent injurious strains in cooling.

Major Wade informs us that time and repose have a surprising effect in removing strains caused by the unequal coolings of iron castings.

Great improvements have been made in improving the quality of iron guns. Guns cast
prior to 1841 had a density of 7.148, with a tenacity of 23,638. Guns cast in 1851 had a density of 7.299, with a tenacity of 37,774.

The following Table gives the results of all the trials made for the United States Government, showing the various qualities of different metals:

<table>
<thead>
<tr>
<th>Metals</th>
<th>Density</th>
<th>Tenacity</th>
<th>Transverse Strength</th>
<th>Tension At Half Degree</th>
<th>Ultimate</th>
<th>Compressive Strength</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-iron:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least</td>
<td>6.900</td>
<td>9.000</td>
<td>5,000</td>
<td>3.861</td>
<td>5.665</td>
<td>84,592</td>
<td>4.57</td>
</tr>
<tr>
<td>Greatest</td>
<td>7.400</td>
<td>11,500</td>
<td>3,197</td>
<td>4.298</td>
<td>7,700</td>
<td>127,720</td>
<td>12.14</td>
</tr>
<tr>
<td>Wrought iron:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least</td>
<td>7.704</td>
<td>38,027</td>
<td>6,500</td>
<td>3.197</td>
<td>-</td>
<td>40,000</td>
<td>10.45</td>
</tr>
<tr>
<td>Greatest</td>
<td>7.858</td>
<td>74,592</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>127,720</td>
<td>12.14</td>
</tr>
<tr>
<td>Bronze:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least</td>
<td>7.978</td>
<td>17,688</td>
<td>-</td>
<td>2.021</td>
<td>5.511</td>
<td>-</td>
<td>4.57</td>
</tr>
<tr>
<td>Greatest</td>
<td>8.953</td>
<td>36,786</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6.514</td>
<td>6.94</td>
</tr>
<tr>
<td>Cast-steel:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least</td>
<td>7.729</td>
<td>-</td>
<td>23,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Greatest</td>
<td>7.862</td>
<td>128,000</td>
<td>23,000</td>
<td>-</td>
<td>198,944</td>
<td>381,985</td>
<td></td>
</tr>
</tbody>
</table>

The following analyses of the metal of iron guns of three qualities are important:

### Influence of Single Ingredients.

<table>
<thead>
<tr>
<th>Classes</th>
<th>Mechanical Tests</th>
<th>Chemical Constituents.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specific Gravity</td>
<td>Combined Carbon.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tensile Strength</td>
<td>Graphite.</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7.204</td>
<td>28,865</td>
<td>0.077</td>
</tr>
<tr>
<td>2</td>
<td>7.140</td>
<td>24,767</td>
<td>0.017</td>
</tr>
<tr>
<td>3</td>
<td>7.088</td>
<td>20,176</td>
<td>0.036</td>
</tr>
</tbody>
</table>

### Influence of two or more Ingredients.

<table>
<thead>
<tr>
<th>Classes</th>
<th>Mechanical Tests</th>
<th>Chemical Constituents.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specific Gravity</td>
<td>Tensile Strength.</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7.204</td>
<td>28,865</td>
<td>0.077</td>
</tr>
<tr>
<td>2</td>
<td>7.140</td>
<td>24,767</td>
<td>0.017</td>
</tr>
<tr>
<td>3</td>
<td>7.088</td>
<td>20,176</td>
<td>0.036</td>
</tr>
</tbody>
</table>

An inspection of the first of the foregoing tables, representing the average amount of each foreign ingredient in gun-metal deduced from all the analyses, shows a considerable difference in the proportions of those ingredients in each of the three classes into which guns are divided. It will be observed, that while the proportion of combined carbon diminishes from the 1st to the 3d class, that of silicium similarly increases, so that their united amounts are nearly the same. In other words, it appears that silicium can replace the carbon to a certain extent; but that the quality of the metal is injured where the amount of the silicium approaches that of the carbon. Karsten made a similar observation in determining the limits between cast-iron and steel, but did not notice the influence of that substitution.

But the differences become more striking by combining the ingredients variously together, as in the second of those tables; and especially by comparing the extremes, which are each derived from a larger number of observations than the mean.

After showing the total amount of carbon, (both combined and uncombined,) silicium and combined carbon are thrown together, which indicates the replacement by silicium of that portion of carbon set free in the form of graphite. The column "silicium and slag" shows the general depreciation of the metal as the silicious metal increases.—From the Report of Campbell Morfit and James C. Booth to the Ordnance Office, United States Army.
The following analyses, (rejecting those substances of which only a mere trace has been discovered,) from the same chemists, are selected as showing striking peculiarities:—

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 32-pdr., which endured the extreme proof.</td>
<td>0.8350</td>
<td>0.0200</td>
<td>0.0200</td>
<td>0.0076</td>
<td>0.0050</td>
<td>0.0035</td>
<td>0.0210</td>
<td>0.0028</td>
<td>0.0106</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. 32-pdr., which endured the extreme proof.</td>
<td>0.8250</td>
<td>0.0200</td>
<td>0.0200</td>
<td>0.0076</td>
<td>0.0050</td>
<td>0.0035</td>
<td>0.0210</td>
<td>0.0028</td>
<td>0.0106</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-pdr., which endured the extreme proof.</td>
<td>0.8250</td>
<td>0.0200</td>
<td>0.0200</td>
<td>0.0076</td>
<td>0.0050</td>
<td>0.0035</td>
<td>0.0210</td>
<td>0.0028</td>
<td>0.0106</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. 42-pounder</td>
<td>0.8240</td>
<td>0.0200</td>
<td>0.0200</td>
<td>0.0076</td>
<td>0.0050</td>
<td>0.0035</td>
<td>0.0210</td>
<td>0.0028</td>
<td>0.0106</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32-pounder</td>
<td>0.8240</td>
<td>0.0200</td>
<td>0.0200</td>
<td>0.0076</td>
<td>0.0050</td>
<td>0.0035</td>
<td>0.0210</td>
<td>0.0028</td>
<td>0.0106</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparison of Weight, Strength, Extensibility, and Stiffness: Cast-iron being unity within practical limits to static forces only.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-iron</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Gun-metal</td>
<td>1.18</td>
<td>0.65</td>
<td>1.27</td>
<td>0.33</td>
<td>0.55</td>
</tr>
<tr>
<td>Wrought iron</td>
<td>1.07</td>
<td>3.00</td>
<td>0.32</td>
<td>2.11</td>
<td>2.11</td>
</tr>
<tr>
<td>Steel</td>
<td>1.07</td>
<td>4.75</td>
<td>0.32</td>
<td>3.15</td>
<td>2.11</td>
</tr>
</tbody>
</table>

We find that wrought-iron guns are more than five-fold as durable as those of gun-metal, and twenty-two times as durable as those of cast-iron. And taking first cost and durability together, gun-metal cannon are about seventy-seven times, and cast-iron guns about thirty times, as dear as wrought-iron artillery. Again: the cost of horse-labor, or other means of transport for equal strength, (and, of course, therefore, for equal effective artillery power,) is about five times as great for gun-metal, and nearly three times as great for cast-iron as for wrought-iron guns. In every respect in which we have submitted them to a comparison, searching and rigid, and that seems to have omitted no important point of inquiry, wrought iron stands pre-eminently superior to every other material for the fabrication of ordnance.—United States Report.

The advantages possessed by rolled bars for the construction of artillery are thus summed up by Mr. Mallet, in his "Memoir on Artillery":—

1. The iron constituting the integrant parts is all in moderate-sized, straight, prismatic pieces, formed of rolled bars only; hence, with its fibre all longitudinal, perfectly uniform, and its extensibility the greatest possible, and in the same direction in which it is to be strained—it is, therefore, a better material than any forged iron can, by possibility, be made.

2. The limitation of manufacture of the iron, thus, to rolling, and the dispensing with all massive forgings, insure absolute soundness and uniformity of properties in the material.

3. The limited size of each integrant part, and the mode of preparation and combination, afford unanswerable tests of soundness and of perfect workmanship, step by step, for every portion of the whole: unknown or wilfully concealed defects are impossible.

4. Facility of execution by ordinary tools, and under easily obtained conditions, and without the necessity of either for peculiarly skilled labor on the part of "heavy forge-men," or for steam and other hammers, &c., of unusual power, and very doubtful utility; and hence very considerable reduction in cost as compared with wrought-iron artillery forged in mass.

5. Facility of transport by reduction of weight, as compared with solid guns of the same or of any other known material.

6. A better material than massive forged iron, rolled bars are much more scientifically and advantageously applied; the same section of iron doing much more resisting work, as applied in the gun built-up in compressed and extended plies, than in any solid gun.

7. The introduction thus into cannon of a principle of elasticity, or rather of elastic range, (as in a carriage-spring divided into a number of superimposed leaves,) greater than that due to the modulus of elasticity of the material itself; and so acting, by distribution of the maximum effort of the explosion, upon the rings successively recipient of the strain during the time of the ball's trajectory through the chaise, as materially to relieve its effects upon the gun.
ARTILLERY.

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Considerable attention has been given, of late years, to the construction of very powerful pieces of ordnance. Cast-iron cannon are usually employed, but these very soon become useless when exposed to the sudden shocks of rapid firing. Cast-iron is, comparatively speaking, a weak substance for resisting extension, or for withstanding the explosive energy of gunpowder, compared with that of wrought-iron, the proportion being as 1 to 5; consequently, many attempts have been made to substitute wrought-iron cannon for cast.

A gun, exhibited in 1831 by the Belgian Government, made of cast-iron "peppered with coke and wood," was said to have stood 2,116 rounds, and another, 3,447 rounds, without much injury to the touch-hole or vent. Another is said to have been twice "rebouched," and has stood 6,002 rounds without injury. As few guns of cast-iron will stand more than 800 rounds without becoming unserviceable, this mode of preparing the iron appears to be a great improvement. At St. Sebastian, 2,700 rounds were fired from the English batteries, but, as was observed by an eye-witness, "you could put your fist into the touch-holes."—Colonel James, R. E.

In Prussia they have for some time made cannon of "forged cast-steel." To get over the difficulty of forging the gun with the trunnions on, the gun has been made without them, and a hollow casting with trunnions afterwards slipped over the breech, and secured in its proper position by screening in the casable. The tenacity of this metal must be very great.

Casting of Guns.—Guns have long been cast in a vertical position, and with a certain amount of "head of metal" above the topmost part of the gun itself. One object gained by this (of great value) is to afford a gathering-place for all scoria, or other foreign matter; an end that might be much more effectually accomplished were the metal always run into the cavity of the mould by "gaiters" leading to the bottom, or lowest point, in place of the metal being thrown in at the top, with a fall, at first, of several feet, as is now the common practice, by which much air and scoria are carried down and mixed with the metal, some of which never rises up again, or escapes as "air-bubbles." (See "Mallet on the Physical Conditions Involved in the Construction of Artillery."

Table showing the Increase of Density in Castings of large Size, due to their Solidification under a Head of Metal, varying from two to fourteen Feet:—

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>6.9551</td>
<td>.0082</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>7.0353</td>
<td>.0062</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>48</td>
<td>7.0145</td>
<td>.0312</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>72</td>
<td>7.0938</td>
<td>.0361</td>
<td>72</td>
</tr>
<tr>
<td>5</td>
<td>96</td>
<td>7.0672</td>
<td>.0136</td>
<td>96</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>7.0776</td>
<td>.0154</td>
<td>120</td>
</tr>
<tr>
<td>7</td>
<td>144</td>
<td>7.0907</td>
<td>.0151</td>
<td>144</td>
</tr>
<tr>
<td>8</td>
<td>168</td>
<td>7.1055</td>
<td>.0128</td>
<td>168</td>
</tr>
</tbody>
</table>

The experiments were made upon cylindrical shafts of cast-iron, cast vertically in dry sand-mould, under heads gradually increasing up to fourteen feet in depth, and all poured from "gaiters" at the bottom.

These experiments show an increase of density due to fourteen feet head, about equal to a pressure of 24-8 lbs. per square inch on the casting; from 6.9551 to 7.1055 for Scotch cast-iron.

In the foregoing paper frequent reference has been made to the investigations of Mr. Mallet. His monster mortar promises such results that an especial account of it appears to be required.

About the latter end of 1854, the attention of Mr. Robert Mallet, C. E., was directed to the mathematical consideration of the relative powers of shells in proportion to their increase of size or of diameter. His inquiries resulted in a memoir presented by him to Government, in which he investigated the increase of power in shells with increase of diameter, under the heads of:—1. Their penetrative power; 2. Their increased range and greater accuracy of fire; 3. Their explosive power; 4. Their power of demolition, or of levelling earthworks, buildings, &c.; 5. Their fragmentary missile power; 6. and lastly, their moral effect,—in every case viewing the shell, not as a weapon against troops, but as...
an instrument of destruction to an enemy's works. The result so convinced Mr. Mallet of the rapid rate at which the destructive powers of a shell increase with increase of size, that he was induced to propose to Government the employment of shells of a magnitude never before imagined by any one, namely, of a yard in diameter, and weighing, when in flight, about a ton and a quarter each; and to prepare designs, in several respects novel and peculiar, for the construction of mortars capable of projecting these enormous globes. Such a mortar was made, and on the 18th of October, 1857, the first of those colossal mortars constructed from Mr. Mallet's design was fired on Woolwich Marshes, with charges (of projec-
tion) gradually increasing up to 70 lbs.; and with the latter a shell weighing 2,550 lbs. was thrown a horizontal range of upwards of a mile and a half to a height of probably three-quarters of a mile, and falling, penetrated the compact and then hard dry earth of the Woolwich range to a depth of more than 18 feet, throwing about cart-loads of earth and stones by the mere splashes of the fall of the empty shell. What would have been the crater blown out, if the bursting charge of 400 lbs. of powder had been within! It would be out of place here to attempt to follow Mr. Mallet's mathematical results as to the relative powers of small and large shells; some popular notion, however, of the subject may be given in a few words.

Say we have a 13-inch shell and a 36-inch shell, and, for simplicity, that each has the same proportion of iron and powder in relation to their bulk, or the same density. Roughly, the huge shell may be said to be three times the diameter of the small one. Then, a ring or circle through which the larger one will just pass will have nine times the area of that through which the smaller one will just pass, and the weight of the large shell will be 27 times that of the small one.

If the two shells, then, be thrown at the same angle of elevation and at the same velocity, the larger shell will range greatly further than the small one, for their relative resistances in the air are about as 1 to 9, while their relative energy of motion or momentum is as 1 to 27.

A 13-inch shell, weighing about 180 lbs., is thrown, by a charge of 30 lbs. of powder, barely 4,700 yards. While, with not much more than double this amount of powder, the 36-inch shell, of more than 14 times its weight, can be thrown 2,650 yards, or much more than half the distance.

The explosive power, it is obvious, is approximately proportionate to the weight of pow-
der; but, by calculations, of which the result only can here be given, Mr. Mallet has shown that the total power of demolition—that is to say, the absolute amount of damage done in throwing down buildings, walls, &c., &c.—by one 36-inch shell, is 1,600 times that possible to be done by one 13-inch shell; and that an object which a 15-inch shell could just over-
turn at one yard from its centre, will be overthrown by the 36-inch shell at 40 yards' distance.

A 13-inch shell penetrates, on falling upon compact earth, about 2½ feet. The Antwerp shell penetrated 7 feet. The 36-inch shell penetrated 16 to 18 feet. The funnel-shaped cavity, or "crater," of earth blown out by the explosion of a buried shell, is always a sim-
ilar figure, called a "parabola," and its diameter at the surface, produced by the 13-inch shell, is about 7 feet, and by the 36-inch shell about 40 feet.

Shells.—The hollow explosive projectiles that we call shells or bombs are a very old invention. Under the name of "côinages," they consisted of rudely formed globes of plate iron soldered together, filled with gunpowder and all sorts of miscellaneous "mitraille." These were thrown to short distances both from "pierrières" (a sort of mortar) and from catapults, as early as 1495 at Naples, 1500 at Padua, 1520 at Helberg, 1532 at Rhodes, and 1542 at Boulogne, Liéges. About the middle of the 15th century, bombs of cast-iron seem to have come into use; an Englishman, named Malthus, learned the art of throwing them from the Dutch, and perfected the system for the French armies—being the first to throw shells in France, at the siege of La Mothe, in 1648. The diameter of the bomb seems at that time to have become fixed at 18 inches—the old Paris foot—and at this it remains (with very few exceptional cases) down to the present day.

A few attempts to increase the size and power of these projectiles have been made at different periods, but never with the practical skill necessary to success; for example, 18-
inch shells were thrown by the French, at the siege of Tournay, in 1719; whereas, just a century before, the Swedes threw shells of 462 lbs. weight, and holding 40 lbs. of powder. The French, when they occupied Algiers in 1830, found numbers of old shells of nearly 900 lbs. in weight, and in almost every arsenal and fortress in Europe one or two old 16-inch and 18-inch shells are to be found. No attempt was made in modern days to realize the vast accession of power that such large shells confer, until the year 1882, when the "mo-
uster mortar," as it was then called, of 24 inches' calibre, designed by Colonel Paixhans, (the author of the Paixhans gun,) was constructed by order of Baron Evain, the Belgian minis-
ter of war, and attempted to be used by the French at the siege of the citadel at Antwerp, but with the worst possible success. The mortar, a crude cylindrical mass of cast-iron, sunk in a bed of timber weighing about 8 tons, and provided neither with adequate means.
for "laying" it, nor for charging it—the heavy shells weighing, when filled with 99 lbs. of powder, 1,015 lbs. each—could with difficulty be fired three rounds in two hours, while the shells themselves were very badly proportioned.

One of these shells fell nearly close to the powder magazine, but did not explode; had it fallen upon the presumed bomb-proof arch of the magazine, containing 200,000 lbs. of powder, it would have pierced it, according to the opinion of all the military engineers present at the siege; and so closed the enterprise at a blow. The ill success of this mortar prevented for several years any attempt to develop bombs into their legitimate office—as the means of suddenly transferring mines into the body of fortified places—of a power adequate to act with decisive effect upon their works; although some years afterwards a 20-inch mortar was made in England for the Pacha of Egypt, and proved at Woolwich.

But another circumstance still more tended to the neglect of large shells thrown by vertical fire. After repeated trials and many failures, it was found practicable to throw 10-inch (and since that even 15-inch) shells from cannon, or "shell-guns," by projecting them nearly horizontally, or at such low angles that they should "ricochet" and roll along the ground before they burst; and, thus fired, it was soon seen that their destructive power as against troops was greater than if fired at angles approaching 45° of elevation from mortars. Paixhans and his school had pushed a good and useful invention beyond its proper limits, and had lost sight wholly of the all-important fact, that horizontal shell-fire, powerful as it is against troops or shipping, is all but useless as an instrument of destruction to the works (the earthwork and masonry, &c.) of fortified places; for this end, weight and the penetrative power due to the velocity of descent in falling from a great height are indispensable.

No bomb-proof arch (so called) now exists in Europe capable of resisting the tremendous fall of such masses, and the terrible powers of their explosion when 480 lbs. of powder, fired to the very best advantage, put in motion the fragments of more than a ton of iron. No precautions are possible in a fortress; no splinter-proof, no ordinary vaulting, perhaps no casemate, exists capable of resisting their fall and explosion. Such a shell would sink the largest ship or floating battery.

A single 36-inch shell in flight costs £25, and a single 13-inch £2 2s., yet the former is the cheaper projectile; for, according to Mr. Mallet's calculations, to transfer to the point of effect the same weight of bursting powder, we must give—

| 53 shells of 16 inches, at £2 2s. | - | - | - | - | £115 10 0 |
| Against 1 shell of 36 inches | - | - | - | - | 25 0 0 |

Showing a saving in favor of the large shell of £90 10 0.

And this assumes that 53 small shells, or any number of them, could do the work of the single great one.

We must briefly notice the mortars from which these projectiles are proposed to be shot, and of which fig. 46 gives an elevation, with section of bore and chambers and lines of separation in dotted lines.
These mortars are, with the exception of one part, (the base,) and the elm timber ends, formed wholly of wrought iron, in concentric rings, and each entire mortar is separable at pleasure into thirteen separate pieces, the heaviest of which weighs about 11 tons, so that the immense weight when all put together (about 52 tons) is susceptible of easy transport, on ordinary artillery carriages, over rough country, or can be conveniently shipped, stored, or landed. Special mortar nails for the use of these mortars at sea have been designed by their inventor, and novel and more precise methods of pointing, especially at night, than hitherto practised.

It has been for some time the practice in Turkey to make field-pieces like the twisted barrel of a rifle. One of the greatest improvements in modern artillery is the manufacture, by Mr. G. W. Armstrong, of Newcastle-on-Tyne, of field-pieces of this character, which are breech-loading, and have several peculiarities which give them decided advantages over any other piece of artillery. For a further description, see Rifles.

Exportation of arms and ammunition:—

<table>
<thead>
<tr>
<th>Year</th>
<th>Guns</th>
<th>Gunpowder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1852</td>
<td>1853.</td>
</tr>
<tr>
<td>Guns</td>
<td>155,739</td>
<td>161,121</td>
</tr>
<tr>
<td>Gunpowder</td>
<td>258,416</td>
<td>7,140,133</td>
</tr>
</tbody>
</table>

Gun stocks in the rough of wood - - - - - - cwt. 235

ASBESTUS, from überbestro, unconsumable. (Asbeste, Fr.; Asbest, Germ.) When the fibres of the fibrous varieties of amphibole are so slender as to be flexible, it is called asbestos, or amiantus. It is found in Piedmont, Savoy, Salzburg, the Tyrol, Dauphine, Hungary, Silesia; also in Corsica so abundantly as to have been made use of by Dolomites for packing minerals; in the United States, St. Kevern in Cornwall, in Aberdeenshire, in some of the islands north of Scotland, and Greeneland. Asbestos was manufactured into cloth by the ancients, who were well acquainted with its incombustibility. This cloth was used for napkins, which could be cleansed by throwing them into the fire; it was also used as the wick for lamps in the ancient temples; and it is now used for the same purpose by the natives of Greenland. It has been proposed to make paper of this fibrous substance, for the preservation of important matters. An Italian, Chevalier Aldini, constructed pieces of dress which are incombustible. Those for the body, arms, and legs, were formed out of strong cloth steeped in a solution of alum; while those for the head, hands, and feet, were made of cloth of asbestos. A piece of ancient asbestos cloth, preserved in the Vatican, appears to have been formed by mixing asbestos with other fibrous substances; but M. Aldini has executed a piece of nearly the same size, which is superior to it, as it contains no foreign substance. The fibres were prevented from breaking by the action of steam. The cloth is made loose in its fabric, and the threads are about the fiftieth of an inch in diameter. The Society of Encouragement, of Paris, has proposed a prize for the improvement of asbestos cloth. The use of it is now (1858) being exhibited in London.

ASHES. In commerce, the word ashes is applied to the ashes of vegetable substances from which the alkalies are obtained, as Kelp, Barilla, &c., (which see.)

It is the popular name of the vegetable alkali, potash, in an impure state, as procured from the ashes of plants by lixiviation and evaporation. The plants which yield the greatest quantity of potash are wormwood and furnality. See Potash, Pearlash, and for the mode of determining the value of ashes, Alkalimetry.

Our Importations of the various kinds of Ashes were—

<table>
<thead>
<tr>
<th>Year</th>
<th>1855.</th>
<th>1856.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soap ashes, cwt.</td>
<td>235</td>
<td></td>
</tr>
<tr>
<td>Wood ashes, &quot;</td>
<td>26</td>
<td>cwt. 1,073 (vedasir, Fr.; waidasche, Germ.)</td>
</tr>
<tr>
<td>Weed ashes, &quot;</td>
<td>&quot;</td>
<td>350</td>
</tr>
</tbody>
</table>

Unenumerated ditto, value £25,302 £7,181;

and of pearl and pot ashes as follows:—

<table>
<thead>
<tr>
<th>Countries from which imported.</th>
<th>1853.</th>
<th>1854.</th>
<th>1855.</th>
<th>1856.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia - - - - - - -</td>
<td>Cwts. 9,064</td>
<td>Cwts. 3,604</td>
<td>Cwts. 2,934</td>
<td></td>
</tr>
<tr>
<td>Holland - - - - - - -</td>
<td>6,881</td>
<td>3,604</td>
<td>2,934</td>
<td></td>
</tr>
<tr>
<td>Tuscany - - - - - - -</td>
<td>1,854</td>
<td>86,080</td>
<td>71,344</td>
<td>87,246</td>
</tr>
<tr>
<td>British North America - - - - - - -</td>
<td>98,774</td>
<td>18,534</td>
<td>6,473</td>
<td>11,673</td>
</tr>
<tr>
<td>United States - - - - - - -</td>
<td>10,398</td>
<td>86,080</td>
<td>71,344</td>
<td>87,246</td>
</tr>
<tr>
<td>Prize cargoes - - - - - - -</td>
<td>238</td>
<td>867</td>
<td>427</td>
<td>1,127</td>
</tr>
<tr>
<td>Other parts - - - - - - -</td>
<td>155,739</td>
<td>109,701</td>
<td>78,133</td>
<td>105,941</td>
</tr>
</tbody>
</table>
ASHES OF PLANTS. The ashes of all species of woods and weeds are found to contain some alkali, hence it is that the residuary matter, after the combustion of any vegetable matter, is found to act as a stimulant to vegetable growth.

The following analyses of the ashes of plants have been selected from the tables which have been published, by Messrs. Thomas Way and G. Ogston, in the "Journal of the Agricultural Society":—

<table>
<thead>
<tr>
<th>Plant</th>
<th>Starch</th>
<th>Sulphate</th>
<th>Potash</th>
<th>Ashes</th>
<th>Coke</th>
<th>Lime</th>
<th>Magnesia</th>
<th>Sesquisulphate</th>
<th>Sulphate acid</th>
<th>Silica</th>
<th>Carbonic acid</th>
<th>Phosphoric acid</th>
<th>Chlorides of Potassium</th>
<th>Chlorides of Sodium</th>
<th>Total Amount</th>
<th>Percentage of Ash in the Dry Substance</th>
<th>Percentage of Ash in the Fresh Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potash</td>
<td>42.25</td>
<td>25.52</td>
<td>7.44</td>
<td>21.90</td>
<td>29.76</td>
<td>19.51</td>
<td>20.67</td>
<td>17.79</td>
<td>28.70</td>
<td>11.56</td>
<td>218.83</td>
<td>27.61</td>
<td>1.39</td>
<td>11.87</td>
<td>28.42</td>
<td>1.29</td>
<td>11.87</td>
</tr>
<tr>
<td>Soda</td>
<td>32.77</td>
<td>19.13</td>
<td>2.20</td>
<td>-</td>
<td>12.56</td>
<td>10.18</td>
<td>15.36</td>
<td>3.74</td>
<td>17.50</td>
<td>12.69</td>
<td>138.36</td>
<td>2.43</td>
<td>0.07</td>
<td>1.80</td>
<td>1.47</td>
<td>0.07</td>
<td>1.80</td>
</tr>
<tr>
<td>Lime</td>
<td>0.97</td>
<td>1.24</td>
<td>0.50</td>
<td>2.10</td>
<td>2.83</td>
<td>5.91</td>
<td>1.84</td>
<td>8.54</td>
<td>11.93</td>
<td>21.37</td>
<td>179.92</td>
<td>9.76</td>
<td>0.57</td>
<td>1.75</td>
<td>1.13</td>
<td>0.57</td>
<td>1.75</td>
</tr>
<tr>
<td>Magnesia</td>
<td>8.96</td>
<td>11.91</td>
<td>0.98</td>
<td>8.96</td>
<td>12.53</td>
<td>5.91</td>
<td>0.32</td>
<td>1.75</td>
<td>4.78</td>
<td>1.89</td>
<td>16.55</td>
<td>3.78</td>
<td>0.21</td>
<td>0.63</td>
<td>0.99</td>
<td>0.21</td>
<td>0.63</td>
</tr>
<tr>
<td>Sesquisulphate</td>
<td>92.4</td>
<td>92.4</td>
<td>92.4</td>
<td>92.4</td>
<td>92.4</td>
<td>92.4</td>
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</tr>
<tr>
<td>Silica</td>
<td>1.74</td>
<td>1.74</td>
<td>1.74</td>
<td>1.74</td>
<td>1.74</td>
<td>1.74</td>
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<td>1.74</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chlorides of Potassium</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
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<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>Chlorides of Sodium</td>
<td>0.68</td>
<td>0.68</td>
<td>0.68</td>
<td>0.68</td>
<td>0.68</td>
<td>0.68</td>
<td>0.68</td>
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<td>0.68</td>
<td>0.68</td>
</tr>
</tbody>
</table>

ASHPHALTIC MASTIC, used in Paris for large works, is brought down the Rhone from Pyrmont, near Lyssell. It is composed of nearly pure carbonate of lime, and about 9 or 10 per cent of bitumen. When in a state of powder it is mixed with about 7 per cent. of bitumen or mineral pitch, found near the same spot. The powdered asphalt is mixed with the bitumen in a melted state along with clean gravel, and consistency is given to pour it into moulds. Sulphur added to about 1 per cent. makes it very brittle. The asphalt is ductile, and has elasticity to enable it, with the small stones sifted upon it, to resist ordinary wear. Walls having cracked, and parts having fallen, the asphaltic has been seen to stretch and not crack. It has been regarded as a sort of mineral leather. The sun and rain do not appear to affect it; and it answers for abattoirs and barracks, keeps vermin down, and is uninjured by the kicking of horses.

A large roof has been formed in Paris for a store for the Government food, entirely of earthenware tiles, and without timber, the tiles being 9 inches long and 5 wide. The arch is covered with a concrete of lime, sand, and gravel; then with a thin coat of hydraulic mortar; over this, when dry, canvas was tightly stretched; asphaltic mastix was poured in a semi-fluid state, and this formed the finished surface of the roof. The strength of the roof has been purposely tested to bear six tons without yielding, and has borne the accidental fall of a stack of chimneys, with the only effect of bruising the mastic, readily repaired.

ASPHALTUM. (Bitum or Asphalt, Fr.; Asphæl, Germ.) Mineral Pitch; so called from the lake Asphaltites; a variety of bitumen, arising from one of the many peculiar changes of vegetable matter. Asphalto, in common with other varieties of bitumen, is a form of hydrocarbon produced in the interior of the earth by the transformation of carbonate of matter, like all combustible bodies of the same class. Composition, CH₂₆. It is a solid black or brownish-black substance, possessing a bright conchoideal fracture. It fuses at 212° F., burning with a brilliant flame, and emitting a bituminous odor. Specific gravity = 1 to 1.3. Asphalum is insoluble in alcohol, but soluble in about five times its weight of naphtha. See BITUMEN.

This solid shining bitumen, of a deep black color when broken, is found in many parts of Egypt. A thin piece appears of a reddish color when held to the light; when cold, it has no odor; by a moderate heat or by friction, the odor is slight; fully heated, it liquefies, swells, and burns with a thick smoke; the odor given is acrid, strong, and disagreeable.

Spirits of wine dissolves pitch, but only takes a pale color with asphaltum. It is readily procured at Mocha.

In the arts, asphaltum is used as a component of Japan varnish. It is likewise employed as a cement for lining cisterns, and for pavements, as a substitute for flag-stones.—H. W. B.

The following quantities of Asphaltum, or Bittumen Jodacolum, were imported into Great Britain:—In 1855, 1,674 tons; in 1856, 2,707 tons, of which 2,573 tons were from France.
ASSAY and ASSAYING. The process employed in assaying gold bullion, by the present assayers to the Mint and Bank of England, is similar to that practised at the Paris Mint. The quantity operated on is half a gramme. This quantity, having been accurately weighed, is wrapped in paper with a portion of pure silver, about equal to three times that of the gold the alloy is supposed to contain, and submitted to cupellation with lead in the manner described in vol. i. The button is then hammered into a flattened dish, about the size of a sixpence, and afterwards annealed and passed through laminating rolls until it is reduced to a riband from 2½ to 3 inches in length; after which it is again annealed, and coiled into a spiral by rolling between the finger and thumb. The cornet is next placed in a small flask containing about an ounce of pure nitric acid of 22 B. (= 1-180 specific gravity); and boiled for 10 minutes. The acid is carefully poured off, and the cornet again boiled with nitric acid of 52 B. (1-250 specific gravity) for 20 minutes; and this second boiling with the stronger acid is repeated and continued about 10 minutes. In the second and third boilings a small piece of charcoal should be introduced into the flask, as recommended by Gay-Lussac, in order to prevent the ebullition taking place irregularly and with sudden bursts, which would be liable to break the cornet, and eject a portion of the liquid from the flask. The cornet is then washed and annealed as above. The return is made to the Mint in decimals or thousandths, and the assayer's weights are so subdivided as to give him the value in thousandths of the original ½ gramme taken.

To the Bank the return is made to the ¼ of a carat grain better or worse than standard. The late Master of the Mint caused Tables to be prepared for the conversion of the results of assays expressed in carats into decimals, and conversely, which are in general use for this purpose. In order to ascertain the amount of error due to the surcharge, a number of proofs are passed through the process simultaneously with the alloys. These proofs consist of weighed portions of absolutely pure gold, to which is added a proportion of copper equal to that estimated to exist in the alloy to be assayed. The excess of weight in these proofs gives the amount to be deducted. It generally varies from 0'2 to 0'5 parts in 1,000.

The last traces of silver may be removed from the cornet by treating it before the final annealing with fusing bisulphate of potash in a porcelain crucible. When sufficiently cool, the whole is heated with hot water containing a little sulphuric acid, and the cornet dried and ignited. By this means gold may be obtained of almost absolute purity, or 999/1000, as it is termed.

The following examples will show the difference in the results, and the degree of accuracy attainable, by the various methods described:

Ten grains of pure gold, alloyed with three times its weight of silver, cupelled and boiled with acid at 22° B., and 32° B., once weighed 10'016.

Ten grains of a half-sovereign, with silver, &c., and acid at 22°, and twice at 32° B.,
gave 91'54
again, 91'56

With acid, as before, and bisulphate of potash, 91'52
again, 91'52

Pure gold alloyed with copper, to bring it to standard, cupelled with silver and lead, and treated with acids and bisulphate, gave in one case precisely the same as was taken originally, or 999/1000, and in another 999'98.

In accurate assaying of gold bullion, it is of course absolutely necessary that the acids should be pure, and that the silver used should be most carefully freed from the traces of gold which it usually contains.

Instead of charcoal or coke, which are generally used for cupellation, much advantage has been found in employing the best anthracite: reduced to the proper size, it contains very little ash, is free from slag or clinker, and allows the heat to be maintained at one steady temperature for many hours, which is a matter of great importance to the assayer. *

ASTRAGAL. An ornamental moulding, generally used to conceal a junction in either wood or stone.

ASTRAGAL PLANEs. Planes fitted with cutters for forming astragal mouldings. They are commonly known as moulding planes.

ASTRAGAL TOOL, for turning. By using a tool shaped as in fig. 47, the process of forming a moulding or ring is greatly facilitated, as one member of the moulding is completed at one sweep, and we are enabled to repeat it any number of times with exact uniformity.

* The most useful works on this subject are:—Chandelier, "L'Art de l'Essayeur; " the work of Gey-Lussac mentioned in the text; "Manuel complet de l'Essayeur," par Vauquelin, 1836; the most useful little work: Bodemann, "Anleitung zur Berg- und Hüttenmann- nischen Prüfungs-Kunst," Chemnitz, 1857; and (perhaps the best of them all) the "Scheilhandbuch für Essajuers-Gold und Zilveramoden" by Stratingh, Groningen, 1821.
ATOMIC THEORY. Dr. Dalton suggested the happy idea, which has been most fruitful in its results, of accounting for the constancy of chemical combinations by assuming that they were composed of one or more atoms of the several elements, the weight of which atoms is represented by the combining proportions; that carbonic oxide, for instance, contains single atoms of carbon and oxygen, whilst carbonic acid is composed of one atom of carbon and two of oxygen.

It must always be remembered that the combining proportions are purely the results of experiment, and, therefore, incontestable, whatever may be the fate of this theory, which, however, has now stood its ground for many years, and done excellent service to science.

This theory offers a most satisfactory explanation of the different laws of chemical combination.

The fact of bodies uniting only in certain proportions, or multiples of those proportions, is a necessary consequence of the assumption that the weight of the elementary atoms is represented by the combining proportions; for, if they united in any other ratio, it would involve the splitting up of these atoms, which are assumed to be indivisible.

And, of course, the combining proportion of a compound must be the sum of the combining proportions of the constituents, since it contains within itself one or more atoms of the several constituents.

The term atom is, therefore, very often used instead of combining proportion or equivalent, a body being said to contain so many atoms of its elements.

All that is assumed in this theory is, that the atoms are of constant value by weight; the same atoms may be arranged in a different way, and hence, although any particular compound contains always the same elements in the atomic ratios, yet the same atoms may, by difference in arrangement, give rise to bodies agreeing in composition by weight, but differing essentially in properties.

M. Dumas has suggested the subdivision of the combining numbers of certain elements, but this idea is quite subversive of the atomic theory, as it is at present understood.

The atomic theory is further confirmed by the observation, that if the specific heat of the elements be compared, it is found that in a large number of cases the specific heat of quantities of the bodies represented by the atomic weights coincides with each other in a remarkable manner.

The Atomic Theory of Dalton is thus set forth by the author:—

"When any body exists in the elastic state, its ultimate particles are separated from each other to a much greater distance than in any other state; each particle occupies the centre of a comparatively large sphere, and supports its dignity by keeping all the rest—which, by their gravity, or otherwise, are disposed to encroach on it—at a respectful distance. When we attempt to conceive the number of particles in an atmosphere, it is somewhat like attempting to conceive the number of stars in the universe—we are confounded with the thought. But if we limit the subject, by taking a given volume of any gas, we seem persuaded that, be the divisions ever so minute, the number of particles must be finite; just as in a given space of the universe, the number of stars and planets cannot be infinite.

"Chemical analysis and synthesis go no further than to the separation of particles one from another, and to their reunion. No new creation or destruction of matter is within the reach of chemical agency. We might as well attempt to introduce a new planet into the solar system, or to annihilate one already in existence, as to create or destroy a particle of hydrogen. All the changes we can produce consist in separating particles that are in a state of cohesion or combination, and joining those that were previously at a distance.

"In all chemical investigations it has justly been considered an important object to ascertain the relative weights of the simples which constitute a compound. But, unfortunately, the inquiry has terminated there; whereas, from the relative weights in the mass, the relative weights of the ultimate particles or atoms of the bodies might have been inferred, from which their number and weights in various other compounds would appear, in order to assist and to guide future investigations, and to correct their results. Now it is one great object of this work ('A New System of Chemical Philosophy') to show the importance and advantage of ascertaining the relative weights of the ultimate particles, both of simple and compound bodies, the number of simple elementary particles which constitute one compound particle, and the number of less compound particles which enter into the formation of each more compound particle.'"

For a full examination of this subject, consult "An Introduction to the Atomic Theory," by Charles Daubeny, M. D.; and "Memories of John Dalton and History of the Atomic Theory," by Robert Angus Smith, Ph. D.

The following Table will show the quantity of precipitate that may be expected to result from the addition of nitrate of silver to 100 grains of a salt of sodium, according to the proportion of chloride and of bromide present:—
### ATOMIC WEIGHTS.

<table>
<thead>
<tr>
<th>Quantity of Salt</th>
<th>Quantity of Precipitate</th>
<th>Quantity of Salt</th>
<th>Quantity of Precipitate</th>
<th>Amount of Precipitate from the two salts</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>184.5</td>
<td>0</td>
<td>9</td>
<td>190.5</td>
</tr>
<tr>
<td>90</td>
<td>166.0</td>
<td>24.5</td>
<td>3</td>
<td>196.5</td>
</tr>
<tr>
<td>80</td>
<td>148.0</td>
<td>48.5</td>
<td>5</td>
<td>202.0</td>
</tr>
<tr>
<td>70</td>
<td>129.5</td>
<td>73.0</td>
<td>7</td>
<td>208.3</td>
</tr>
<tr>
<td>60</td>
<td>111.0</td>
<td>95.5</td>
<td>9</td>
<td>214.0</td>
</tr>
<tr>
<td>50</td>
<td>92.5</td>
<td>121.5</td>
<td>11</td>
<td>220.0</td>
</tr>
<tr>
<td>40</td>
<td>74.0</td>
<td>146.0</td>
<td>13</td>
<td>226.0</td>
</tr>
<tr>
<td>30</td>
<td>56.0</td>
<td>170.0</td>
<td>15</td>
<td>232.0</td>
</tr>
<tr>
<td>20</td>
<td>37.0</td>
<td>195.0</td>
<td>17</td>
<td>238.0</td>
</tr>
<tr>
<td>10</td>
<td>18.5</td>
<td>219.0</td>
<td>19</td>
<td>244.0</td>
</tr>
<tr>
<td>0</td>
<td>0.0</td>
<td>243.0</td>
<td>21</td>
<td>249.0</td>
</tr>
</tbody>
</table>

### ATOMIC WEIGHTS, EQUIVALENT, CHEMICAL EQUIVALENT, COMBINING WEIGHT, OR PROPORTION. The following propositions may be regarded as the laws regulating atomic combination:—

1. The equivalents of elementary bodies represent the smallest proportions in which they enter into combination with each other.

2. The equivalent of a compound body is the sum of the equivalents of its elements.

3. Combination takes place, whether between elements or compounds, either in the proportions of their equivalents, or in multiples of these proportions, and never in submultiples.

4. The law of definite and multiple proportion is, individual compounds always contain exactly the same proportions of their elements. See EQUIVALENTS, CHEMICAL.

### ATOMIC VOLUMES. Recently it has been assumed that the elements unite invariably in equal volumes—when in the gaseous state;—or, in other words, that the atoms of bodies have always the same volume. If this doctrine be maintained, it becomes necessary to alter the atomic weights or combining numbers of certain elements. For example, water contains two volumes of hydrogen to one of oxygen; but, according to the generally received idea, it consists of single atoms of each element; it is clear, therefore, that if we are to assume that the atoms of hydrogen and oxygen have the same volume, we must either halve the atomic weight of hydrogen or double that of oxygen.

Berzelius suggested that all the atomic weights should remain the same, except those of hydrogen, nitrogen, phosphorus, chlorine, bromine, and iodine, which should halve their present values. Gerhardt, on the other hand, adopts the more convenient practice of allowing hydrogen and its congeners to retain their present atomic weights, doubling those of oxygen, sulphur, tellurium, and carbon.

### ATROPINE. (C₁₇H₂₅NO₅). An exceedingly poisonous alkaloid, found in deadly nightshade (Atropa Belladonna) and in stramonium (Datura Stramonium).

### ATTAR OF ROSES, more commonly, OTTO OF ROSES. An essential oil, obtained in India, Turkey, and Persia, from some of the finest varieties of roses. It is procured by distilling rose leaves with water, at as low a temperature as possible. It is said that this perfume is prepared also by exposing the rose leaves in water to the sun; but, from the fact that under the circumstances fermentation would be speedily established, it is not probable that this is a method ever resorted to. By dry distillation from salt-water baths, no doubt the finest attar is obtained. This essential oil is only used as a perfume. Attar of roses is adulterated with sparmaceti and with castor oil dissolved in strong alcohol.

This adulteration may be detected by putting a small drop of the otto of roses on a piece of clean writing paper; by agitation in the air, the volatile oil soon evaporates, leaving no stain if pure; if any fixed oil is present, a greasy spot is left on the paper.

### ATTENUATION. Brewers and distillers employ this term to signify the weakening of saccharine worts during fermentation, by the conversion of the sugar into alcohol and carbonic acid.

### AURUM MOSAICUM or MOSAICUM. MOSAIC GOLD.—For the preparation of Mosaic gold, the following process is recommended by Woulfe. An amalgam of 2 parts of tin and 1 part of mercury is prepared in a hot crucible, and triturated with 1 part of sal-ammoniac, and 1 part of flower of sulphur; the mixture is sublimed in a glass flask upon the sand bath. In breaking the flask after the operation, the sublimate is found to consist, superficially, of sal-ammoniac, then of a layer of cinnamar, and then of a layer of Mosaic gold.

There are several other processes given for the preparation of this bisulphide of tin, but the above probably gives the best results.
AVOCADO PEAR OIL.

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Bergman mentions a native aurum marium from Siberia, containing tin, sulphur, and a small proportion of copper. Dr. John Davy gave the composition as—

<table>
<thead>
<tr>
<th>Tin</th>
<th>100</th>
<th>Sulphur</th>
<th>56.25</th>
</tr>
</thead>
</table>
| Berzelius as—

<table>
<thead>
<tr>
<th>Tin</th>
<th>100</th>
<th>Sulphur</th>
<th>52.3</th>
</tr>
</thead>
</table>

Most gold is employed as a bronzing powder for plaster figures, and it is said to enter sometimes into the composition of aventurine.

AUTOMATIC SOLDERING. A process of soldering by which metals are united either by the ordinary solderers or by lead, under the influence of a flame of hydrogen or of a mixture of hydrogen and common air.

The process of using air and hydrogen was invented in France, by the Count de Richemont. Hydrogen gas is contained in a gasometer, to which a flexible tube is connected, and air is urged from a bellows worked by the foot, through another tube, and on to the blowpipe, where the hydrogen is ignited. By means of the flexible tubes the flame can be moved up and down the line of any joint, and the connecting medium melted. Fig. 48.

This process has been a good deal employed for plumbers' work, especially in our naval arsenals.

AUTOMATIC ARTS. Such arts or manufactures as are carried on by self-acting machinery.

AVENTURINE. (Aventurine, Fr.) A variety of quartz which is minutely spangled throughout with yellow scales of mica; is known as Aventurine quartz. It is usually translucent, and of a gray, brown, or reddish-brown color. There is also an Aventurine feldspar (Feldspat aventuriné, Fr.) Commercially, in France and some other parts of Europe, the name of Pierre de soleil is given to the finest varieties of the feldspar aventurine, some lapidaries, however, calling this stone by the name of Aventurine orientale. This aventurine occurs at Capa de Gata, in Spain; it has reddish and yellow internal reflections.

An artificial aventurine has been manufactured on a large scale for a long period, at the glass-works of Murano, near Venice. According to Wöhler's examination, aventurine glass owes its golden iridescence to a crystalline separation of metallic copper from the mass colored brown by the peroxide of iron.

C. Karsten analyzed the artificial aventurine from the glass manufactories of Bigaglia, in Venice, and found it to contain—

| Silice acid | 67.3 |
| Lame | 9.0 |
| Protoxide of iron | 3.4 |
| Binoxide of tin | 2.3 |
| Protoxide of lead | 1.0 |
| Metallic copper | 4.0 |
| Potash | 5.3 |
| Soda | 7.0 |

These numbers agree in a remarkable manner with the results formerly obtained by Peligot, and may therefore be regarded as truly representing the composition of the glass.

AVERRUNCTOR. A pair of pruning shears, which, on being mounted on a pole some ten feet long, and actuated by a string of catgut, can be used for pruning at a considerable distance above the head.

AVOCADO PEAR OIL. An oil obtained from the oleaginous fruit the Avocado pear-tree, (Laurus Persica), a native of Trinidad. A portion of this oil having been submitted to Dr. Hofmann by the Governor of Trinidad, he reported on its character and composition. The following is an extract from his report:

'According to my present experience, the oil of the Avocado pear is less valuable as a lubricating material. To make it fit for the higher classes of machinery, its mucilaginous constituents must be removed by the same refining process requisite for its adaptation in illuminating purposes. This will slightly increase its price. Even when purified it retains an attraction for oxygen, by which it becomes rapidly colored, viscid, and actually acid. It cannot, either in price or in applicability, compete with that remarkable substance 'Paraf-
fine oil,' which has been discovered within the last year by Mr. James Young, and which is now manufactured by him on a large scale, by the distillation, at a low temperature, of several varieties of coal.

On the other hand, the oil of the Avocado pear is very applicable for the production of good soap. I have the honor of transmitting to your Excellency specimens prepared with the oil; the smaller one, which possesses a yellow color, is prepared with the oil in its original condition; the larger one is made with a portion of oil which had previously been bleached by chlorine. From this specimen it is obvious that the oil, although poor in stearine, nevertheless furnishes a soap which is tolerably hard and solid. It ought to be remembered that it is difficult to obtain a hard soap by working on the small scale prescribed by the limited amount of material at my disposal. For the perfect elaboration of this investigation also, a large supply of material will be of great advantage; but I have even now no hesitation in stating, that, for the purposes of the soap-maker, the oil of the Avocado pear will have, at least, the same value as palm oil."

AZIMUTH COMPASS. The azimuth compass is used chiefly to note the actual magnetic azimuth, or that arch of the horizon intercepted between the azimuth, or vertical circle passing through the centre of any heavenly body, and the magnetic meridian. The card of the azimuth compass is subdivided into exact degrees, minutes, and seconds. To the box is fixed two "sights," through which the sun or a star may be viewed. The position into which the index of the sights must be turned to see it, will indicate on the card the azimuth of the star. When the observations are intended to be exact, telescopes take the place of the sights. By this instrument we note the actual magnetic azimuth; and, as we know the azimuth calculated from the N. and S. line, the variation of the needle is readily found.

AYR STONE, called also Scotch stone and snake stone, is much in request as a polishing stone for marble and for copper plates. These stones are always kept damp, or even wet, to prevent their becoming hard.

The harder varieties of Ayr stone are now employed as whetstones. AZURITE. This term has been applied to several blue minerals, which have little in common. Bendant and Dana use it to signify the blue carbonate of copper—now termed Chessylite by Brook and Miller, from its occurring in fine crystalline forms at Chessy, near Lyons; hence commonly called Chessy copper. Azurite is also applied to the Lasculite of Dana; which is again called Azure stone and blue spar by others.

The same term is also given to the Lapis lazuli, from which ultramarine is obtained. This want of agreement between mineralogists—leading them to adopt names independent of one another (names frequently taken from some locality in which the writer knows the mineral to be found)—produces great confusion, and retards the progress of knowledge.

BACK. A mining term. The back of a mineral lode is that part which is nearest the surface. The back of a level is the ground between it and the level above it.

BACK. A brewer's utensil.

BAIN-MARIE. A vessel of water in which saucers, &c., are placed to warm food.

BAIZE. A coarse woollen stuff with a long nap, sometimes frized on one side.

BAKERS' SALT. The sesquicarbonate of ammonia, so called because it is often used as a substitute for yeast in bread and pastry.

BAL. An ancient Cornish miner's term for a mine. Balamandian is a name given to girls working at a mine.

BALACHONG. An article of food much used in the Eastern Archipelago, consisting of fish and shrimps pounded together.

BALANCE FOR WEIGHING COIN introduced at the Bank of England in the year 1841.

Mr. William Cotton, then Deputy-Governor, and during the two succeeding years Governor of the Bank, had long regarded the mode of weighing by common hand-balances with dissatisfaction on account of its injurious effect upon the "teller," or weigher, owing to the straining of the optic nerve by constant watching of the beam indicator, and the necessity of reducing the functions of the mind to the narrow office of influencing a few constantly repeated actions. Such monotonous labor could not but endure for hours together without moments of forgetfulness resulting in errors. Errors more constant, although less in amount, were found to be due to the rapid wearing of the knife-edges of the beam; currents of air also acting upon the pans produced undesired results; and even the breath of the "teller" sometimes turned the scale; so that, in hand-weighing, the errors not frequently amounted to a, and even half a grain. At the very best, the hand-scale working at the rate of 3,000 per six hours could not indicate nearer than a grain.
BALANCE FOR WEIGHING COIN.

Upon taking into consideration the inconveniences and defects of the hand-weighing system, Mr. Cotton conceived the idea that it might be superseded by a machine defended from external influences, and contrived so as to weigh coins as fast as by hand, and within the same accuracy. He subsequently communicated his plan to Mr. David Napier, of York Road, Lambeth, engineer, who undertook the construction of an experimental machine. Its capabilities were tested and reported upon by Mr. William Miller, of the Bank. The result was most satisfactory; more “automaton balances” were ordered; and from time to time further additions have been made, so that at present there are ten in daily operation at the Bank of England. But it was not without a struggle that the time-hallowed institution of tellers passed away. There were interests opposed to the introduction of improved, more ready, and less expensive methods; and it required all Mr. Cotton’s energy of character, the influence of his intelligence in mechanics, as well as that arising from his position in the Direction, to obtain the adoption of an invention by which a very large annual saving has been effected.

The mechanical adaptation of the principles involved in the Automaton Balance, as contrived by Mr. Napier, may be shortly explained:—The weighing beam, of steel, is forked at the ends, each extremity forming a knife-edge; and in the centre the fulcrum knife-edge extends on each side of the plate of the beam, and rests in hollows cut in a bowed cross-bar fixed to the under side of a rectangular brass plate, about 12 inches square, which is supported at the corners by columns fixed to a cast-iron table raised a convenient height on a stand of the same material. To form a complete enclosing case, plates of metal or glass are slid into grooves down the columns. When the beam is resting with its centre knife-edge in the hollows of the cross-bar just referred to, its upper part is nearly on a level with the under side of the brass plate, in which a long slot is made so that the beam can be taken out when the feeding slide-box, and its plate, which covers this slot, are removed. On the top of the covering plate, is the feeding slide a tube hopper is placed, and a plate communicates with the slide; another hole is pierced in the same plate exactly over one end of the beam, upon the knife-edges of which a long rod is suspended by hollows formed in a cross-bar close to its upper end, where the weighing platform is fitted. A rod is also suspended at the other end of the beam in a similar manner; but instead of a weighing plate, it has a knob at top, which, when the beam is horizontal, comes into contact with an adjustable agate point. The lower end of this pendant rod is stirrup-shaped, for holding the counterpoise. Two displacing slides are provided, one on each side of the feeding slide, and at right angles to each other; and a gripping apparatus is fixed to the under side of the brass top plate, arranged so as to hold the pendant on which the scale-plate is fitted during the change of the coin. A dipping-finger is also attached to the frame of the gripping apparatus, its end passing into a small slot in the pendant rod, and acting upon a knife-edge at the lower end of the slot. There are four shafts crossing the machine; the one through which the power is applied is placed low and at the centre, and carries a pinion which gears with a wheel of twice its diameter on a shaft above; this wheel gears with two similar wheels fixed to shafts on each side of the centre. Cams for acting upon the feeding slide through the medium of a rocking frame, are carried by the shaft placed at the end of the machine where the counterpoise hangs, and the other two shafts on the same level bear cams for working the gripping apparatus, the dipping-finger, and the displacing slides.

Having described, as clearly and as popularly as we can, the general features of the mechanism, we will proceed to indicate its manner of action. Suppose, then, the hopper filled, and a hollow inclined plane about two feet long, which has been added to the hopper by the inventive genius of one of the gentlemen in the weighing-room, also loaded its whole length with the pieces to be weighed, the machine is set in motion, and the feeding slide pushes the lowest piece forward on to the weighing plate, the grippers meantime holding fast by the neck of the pendant, so as to keep the plate perfectly steady; the dipping-finger is also at its lowest position, and resting upon the knife-edge at the bottom of the slot in the pendant rod, thus keeping the beam horizontal, and the knob on the counterpoise pendant, in contact with the agate point already mentioned. When the coin is fairly placed on the weighing-plate, the grippers let go their hold of the pendant rod, and the dipping-finger is raised by its cam; if then the coin is too light, the coin end of the beam will rise along with the dipping-finger, and the counterpoise end will descend; if heavy, the beam will remain without motion, the agate point preventing it. As soon as the dipping-finger attains the proper height, and thus has allowed sufficient time for the weight of the coin to be decided, the grippers close and hold the pendant, and consequently the scale or weighing-plate, at the high level, if the coin has proved light, and been raised by the excess of weight in the counterpoise; and at the low or original level, if the coin has proved heavy. One of the displacing slides now comes forward and passes under the coin, if it is light, and therefore raised to the high level; but knocks it off, if remaining on the low level, by a “clapper” box. The other displacing slide then advances the Napiers of higher than the first, and removes the light piece which the other has missed, into the receptacle for the light coin. During these operations the feeding slide has brought forward
BALE.

another coin, and the process just described is repeated. The attendant is only required to replenish the inclined plane at intervals, and remove the assorted coin from the boxes. The perfection of the workmanship, and the harmony of the various actions of the machine, will be best appreciated from the fact, that 25 pieces are weighed per minute to the fineness of 1/100 of a grain. This combination of great speed and accuracy would not have been possible with a beam made in the ordinary way, having the centre of gravity below the centre of action; and it was pronounced to be so by the late Mr. Clement, the constructor of Mr. Babbage's Calculating Machine. But Mr. Napier overcame the difficulty by raising the centre of gravity so as to coincide with the centre of action, which gave it much greater sensibility; and he provided the dipping-finger, to bring the beam to a horizontal position after each weighing, instead of an influencing weight in the beam itself.

The wear and tear of these machines are found to be very small indeed; those supplied in 1842 and 1843, and in daily use ever since, weigh with the same accuracy as at first, although they may be said to have cost nothing for repairs. The principal cause of this long-continued perfection is that the beam does not oscillate, unless the coin is light, and even then the space passed through does not exceed the thickness of the coin.

In 1851, when the Moneyers were no longer masters of the Royal Mint, and the new authorities began to regard the process of weighing the coin in detail by hand as a laborious, expensive, and inaccurate method, the firm of Napier & Son, at an interview with Sir John Herschel, the Master, and Captain Harness, the Deputy-Master, received an order for five machines, to be designed to suit the requirements of the Mint, which involved a complete change in the mechanical arrangement of the machine as used at the Bank, it being necessary to divide the "blanks," or pieces before they are struck, into three classes: "too light," "too heavy," and "medium," or those varying between certain given limits. It would occupy too much space to attempt a description of the mechanical disposition of this machine, and it could not be satisfactorily accomplished without the aid of drawings; let it suffice, then, to say that the displacing-slides are removed, and a long vibrating conducting-tube receives the blanks as they are in turn pushed off the weighing-plate by the on-coming blanks; but, according to the weight of the blank, so the lower end of the tube is found to be opposite to one of three openings leading into three boxes. The tube is sustained in its proper position, during the descent of the blank last weighed through it, by a stop-finger, the height of which is regulated by a dipping-finger, which comes down upon a knife-edge at the lower end of a slot in the pendant-rod just when the grippers have laid hold of the rod after the weighing is finished; this finger thus ascertains the level which the knife-edge has attained, and as it brings down the stop-finger with it, the guide-tube, which is furnished with three rests, as steps in a stair, vibrates against the stop-finger, one of the three steps coming in contact with it, according to the level of the stop-finger; and the end of the guide-tube takes its place opposite the channel leading to the box in which the blank should be found. The counterpoise employed is less than the true standard weight, by the quantity which may be allowed as the limit in that direction; and in case a blank is too heavy, not only is the counterpoise raised, but a small weight, equal to the range allowed between the "too light" and "too heavy," is raised also; this small weight comes to rest on supports provided for it when the beam is horizontal, and is only disturbed by a too heavy blank.

These machines have proved even more accurate and rapid than those made for the Bank; and Professor Graham, the present master, amongst the improvements introduced by him into the system of the Mint, has added to the number, and dispensed entirely with the hand-weighing. It is said that the saving accruing from this change alone amounts to nearly £2,000 per annum.

BALE. A package of silk, linen, or woollen, is so called.

BALLISTIC PENDULUM. An instrument for measuring the force of cannon-balls. The ballista was an instrument used by the ancients to throw darts, &c. The ballistic pendulum derives its name from this; it consists of an iron cylinder, closed at one end, suspended as a pendulum. A ball being fired into the open end, deflects the pendulum according to the force of the blow received from the ball, thus measuring its power.

BALLOON. In France, a quantity of glass. Of white glass, 25 bundles of six plates each; of colored glass, 12½ bundles of three plates each are called balloons.

BALLOON, AIR. A varnished silk or other bag filled with gas, or warm air, which, being specifically lighter than the atmosphere, ascends in it. Numerous attempts have been made to bring air balloons under the control of the aeronaut, so as to guide them across the currents of the atmosphere; but all of these have proved unsuccessful, the balloon and its voyagers having always moved with the aerial current, in spite of the mechanical appliances which have been adopted.

BAMBOO. (Bambus, Fr.; Indischeischer Rehr, Ger.) A species of cane, the Bambus arundinacea of botanists. It is a most important vegetable product in the East, where it is used in the construction of houses, boats, bridges, &c. Its grain is used for bread; its fibre is manufactured into paper.
BARLEY. 129

Walking sticks are frequently said to be of bamboo; they are the ratan, a different plant.

**BANDOLINE**, called also *clypehitique* and *fixature*, a mucilage of Carrageen moss; used for stiffening the hair and keeping it in order.

**BARBARY GUM.** Sometimes called *Morocco gum*. The product of the *Acacia gummi-fera*. Imported from Tripoli, Barbary, and Morocco.

**BARDERRY.** (Berberis, Lat.; *Epine-sinette*, Fr.) It is probable that this name has been given to this plant from its spines, or *barbs*. The name *Oxyanthus*, also given to it, indicates a like origin.

**BARRIL.** (Sulde, Barillar, Fr.; Barilla, Germ.) A crude soda, procured by the incineration of the *sosolda* soda, a plant cultivated for this purpose in Spain, Sicily, Sar- dinia, and the Canary Islands. In Alicante the plants are raised from seed, which is sown at the close of the year, and they are usually fit to be gathered in September following. In October the plants are usually burned. For this purpose holes are made in the earth, capable of containing a ton or a ton and a half of soda. Iron bars are laid across these cavities, and the dried plants, stratified with dry seeds, are placed upon them. The whole is set on fire. The alkali contained in the plants is fused, and it flows into the cavity beneath, a red-hot fluid. By constantly heaping on plants, the burning is continued until the pits are full of alkali; they are then covered up with earth, and allowed to cool gradually. The spongy mass of alkali, when sufficiently cold, is broken out, and, without any further preparation, it is ready for shipment. Good barilla usually contains, according to Dr. Ure's analysis, 20 per cent. of real alkali, associated with muriates and sulphates, chiefly of soda, some lime, and alumina, with very little sulphur. Caustic leys made from it were formerly used in the finishing process of the hard soap manufacture.

The manufacture of barilla has greatly declined since the introduction of Le Blanc's process for artificially manufacturing soda from common salt. The quantity of barilla and alkali imported in 1850 amounted to 34,880 cwts., and in 1853 to 45,740 cwts.; in 1856 the importation was 54,608 cwts.

**BARK.** The outer rind of plants. Many varieties of barks are known to commerce, but the term is especially used to express either Peruvian or Jesuite's bark, a pharmaceutical remedy, or Oak bark, which is very extensively used by tanners and dyers.

The varieties known in commerce are:

- **Cork Bark.** (Fr. Liège; Kerk, Germ.)
- **Oak Bark.** (Fr. brul., Fr.; Eicheuriinde, Germ.)
- **Peruvian Bark.** (Quinquina, Fr.; Chincomb, Germ.)
- **Quercifron Bark.**
- **Wattle Bark.**

**BARLEY.** (Orge, Fr.; Gerstengrau, Germ.; Hordeum, Linn.) This term is supposed to be derived from *hordus*, heavy, because the bread made from it is very heavy. Barley belongs to the class *Eudicots*, or *Monocotyledons*; *Grain Alliance*, of Linley: natural order *Graminaeae*. There are four species of barley cultivated in this country:

1. **Hordeum heazenkeith.** Six-rowed barley.
2. **Hordeum euphyres.** The Scotch bero or bigg; the four-rowed barley.
3. **Hordeum svecirom.** Putney, fan, sprad, or battledore barley.
4. **Hordeum distichon.** Two-rowed or long-eared barley.

Barley and oats are the cereals whose cultivation extends farthest north in Europe. The specific gravity of English barley varies from 1·25 to 1·33; of bigg from 1·27 to 1·28; the weight of the husk of barley is 34%, that of bigg 36%. Specific gravity of barley is 1·238, by Dr. Ure's trials. 1,000 parts of barley flour contain, according to Einhof, 720 of starch, 56 sugar, 50 mucilage, 36·9 gluten, 12·8 vegetable albumen, 100 water, 2·5 phosphate of lime, 0·5 fibrous or ligneous matter.

From the examination instituted by the Royal Agricultural Society of England, and carried out under the directions of Messrs. Way and Ogston, the following results have been arrived at:

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>12·00</td>
<td>1·260</td>
<td>2·43</td>
</tr>
<tr>
<td>Chevalier barley</td>
<td>10·00</td>
<td>1·284</td>
<td>2·92</td>
</tr>
<tr>
<td>Ditto</td>
<td>16·00</td>
<td>1·288</td>
<td>2·38</td>
</tr>
<tr>
<td>Ditto, from Moldavia</td>
<td>11·00</td>
<td>1·288</td>
<td>2·75</td>
</tr>
<tr>
<td>Ditto</td>
<td>15·00</td>
<td>-</td>
<td>14·23</td>
</tr>
<tr>
<td>Grains of Chevalier barley</td>
<td>13·00</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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The analyses of several varieties gave as the composition of the ashes of the grains of barley:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Potash</td>
<td>21.14</td>
<td>20.77</td>
<td>37.55</td>
<td>7.70</td>
</tr>
<tr>
<td>Soda</td>
<td>-</td>
<td>-</td>
<td>4.26</td>
<td>1.00</td>
</tr>
<tr>
<td>Lime</td>
<td>1.65</td>
<td>1.48</td>
<td>1.21</td>
<td>1.00</td>
</tr>
<tr>
<td>Magnesia</td>
<td>7.26</td>
<td>7.45</td>
<td>10.17</td>
<td>1.26</td>
</tr>
<tr>
<td>Sesquiside of iron</td>
<td>23.3</td>
<td>0.61</td>
<td>1.02</td>
<td>1.46</td>
</tr>
<tr>
<td>Sulphric acid</td>
<td>1.21</td>
<td>0.79</td>
<td>0.27</td>
<td>0.99</td>
</tr>
<tr>
<td>Silica</td>
<td>30.68</td>
<td>32.73</td>
<td>24.56</td>
<td>70.77</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>28.52</td>
<td>31.69</td>
<td>28.64</td>
<td>1.99</td>
</tr>
<tr>
<td>Chloride of sodium</td>
<td>1.01</td>
<td>-</td>
<td>1.47</td>
<td>1.10</td>
</tr>
</tbody>
</table>

In the "Synopsis of the Vegetable Products of Scotland," by Peter Lawson and Son, will be found the best description of all the different varieties of barley; and, since the Lawsonian collection is in the museum of the Royal Botanic Gardens at Kew, the grains can be examined readily by all who take any interest in the subject. A few only of the varieties will be noticed.

The true six-rowed Barley, known also as Pomeranian and as six-rowed white winter barley.—This is a coarse barley, but hardy and prolific. It is occasionally sown in France, and also in this country, sometimes as a winter and sometimes as a spring barley, and is found to answer pretty well as either.

Naked two-rowed.—Bar long, containing twenty-eight or thirty very large grains, which separate from the pale, or chaff, in the manner of wheat. This variety has been introduced to the notice of agriculturalists at various times, and under different names, but its cultivation has never been carried to any great extent.

Common Beere, Bigg, or rough Barley.—This variety is chiefly cultivated in the Highlands of Scotland, and in the Lowlands on exposed inferior soils.

*Victoria.*—A superior variety of the old bigg, compared with which it produces longer straw, and is long-eared, often containing 70 or 100 grains in each. Instances have been known of its yielding 13 quarters per acre, and weighing as much as 96 lbs. per bushel.

Beyond these there are, the winter black; the winter white; old Scottish four-rowed; naked, golden, or Italian; Suffolk or Norfolk, and Short-necked; cultivated in various districts, and with varying qualities.

**BAREGE.**

A woollen fabric, in both warp and woof, which takes its name from the district in which it was first manufactured—the especial locality being a little village named Aroseens, in the beautiful valley of Barreges. It was first employed as an ornament for the head, especially for sacred ceremonies, as baptism and marriage. Paris subsequently became celebrated for its bareges, but these were generally woven with a warp of silk. Enormous quantities of cheap bareges are now made with a warp of cotton.

** BARREL.** *(Baril, Fr.)* A round vessel, or cask, of greater length than breadth, made of staves, and hooped.

The English barrel—wine measure contains 314 gallons.

- (old) beer **"** 30 **"**
- (old) ale **"** 32 **"**
- beer vinegar **"** 34 **"**

contains 126 Paris pints.

The ale and beer barrels were equalized to 34 gallons by a statute of William and Mary. The wine gallon, by a statute of Anne, was declared to be 291 cubic inches; the beer gallon being usually reckoned as 282 cubic inches.

The imperial gallon is 277.274 cubic inches.

The old barrels now in use are as follows:—

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wine barrel</td>
<td></td>
<td>26$^{3/4}$ imperial gallons.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ale (London)</td>
<td></td>
<td>36$^{3/4}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beer <strong>&quot;</strong></td>
<td></td>
<td>36$^{3/4}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ale and beer, for England <strong>&quot;</strong></td>
<td></td>
<td>34$^{3/4}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The **baril de Florence** is equivalent to 20 bottles.

The Connecticut barrel for liquors is 31$^{1/4}$ gallons, each gallon to contain 251 cubic inches.

The statute barrel of America must be from 28 to 31 gallons.

The barrel of flour, New York, must contain either 186 lbs. or 223 lbs. net weight.

The barrel of beef or pork in New York and Connecticut is 200 lbs.

A barrel of Essex butter is 106 lbs.

A barrel of Suffolk butter is 256 lbs.

A barrel of herrings should hold 1,000 fish.

A barrel of salmon should measure 42 gallons.
BARWOOD.

BAROMETER. A name given to one of the most important instruments of meteorology. This name signifies a measurer of weight — the column of mercury in the tube of the barometer being exactly balanced against the weight of a column of air of the same diameter, reaching from the surface of the earth to the extreme limits of the atmosphere. The length of this column of mercury is never more than thirty-one inches; below that point it may vary, according to conditions, through several inches.

There have been many useful applications of the barometer, but the only one with which this dictionary has to deal appears to be the following —

Barometer, Mackworth's Underground. — In the goafs, or old workings, of some mines, hollows exist, in which explosive or noxious gases tend to accumulate in considerable quantity. When the barometer falls, these gases expand and approach or enter the working places of the mine, producing disastrous results to life or health. To enable the manager of a mine to foresee these contingencies, he has but to construct a small model of such a cavity, and let the expansion or contraction of the gas measure itself. In fig. 49, $a$ is a brass vessel, 1/2 inches long and 1/2 inches in diameter, closed at each end. In one end is inserted a copper tube, 1/2 inch in diameter and 12 feet long, $b$. A hole, 2 inches in diameter, being bored 12 feet deep into the solid coal or rock, the brass vessel is pushed to the bottom of it, and the small tube is closely packed round with coal or clay. $c$ is a glass tube, 4 feet long and 1/2 inch in diameter, in which is placed water or oil. As the external atmosphere presses, the surface of the liquid rises or falls, and the scale is graduated by comparison with a standard barometer. The air contained in the brass vessel $a$, and copper tube $b$, is unaffected, or nearly so, by temperature, and no correction has to be made for the latter as in the sympleometer. $a$ and $b$ may be conveniently filled with nitrogen, to prevent the oxidation of the metal; and the surface of the liquid in the glass tube may be made self-registering, either giving maxima and minima, or, by the addition of clock-work, taking diagrams on paper.

BARWOOD. Although distinctions are made between sandal or saunders wood, eamwood, and barwood, they appear to be very nearly allied to each other — at least, the coloring matter is of the same composition. They come, however, from different places.

MM. Girardin and Preissler thus describe this wood: —

This wood, in the state of a coarse powder, is of a bright-red color, without any odor or smell. It imparts sordidly any color to the saliva.

Cold water, in contact with this powder, only acquires a faint tint after five days' maceration. 100 parts of water only dissolve 2-21 of substances consisting of 0-85 coloring matter and of 1-36 saline compounds. Boiling water becomes more strongly colored of a reddish yellow; but, on cooling, it deposits a part of the coloring principle in the form of a red powder. 100 parts of water at 212° dissolve 8-86 of substances consisting of 7-24 coloring principle, and 1-62 salts, especially sulphates and chlorides. On macerating the powder in strong alcohol, the liquid almost immediately acquires a very dark vinous red color. To remove the whole of the color from fifteen grains of this powder, it was necessary to treat it several times with boiling alcohol. The alcoholic liquid contained 0-25 of coloring principle and 0-004 of salt. Barwood contains, therefore, 23 per cent. of red coloring matter; whilst saunders wood, according to Pelletier, only contains 16-75.

The alcoholic solution behaves in the following manner towards re-agents: —

Distilled water added in great quantity — Produces a considerable yellow opalescence. The precipitate is re-dissolved by the fixed alkalies, and the liquor acquires a dark vinous color.

Fixed alkalies

Turn it dark crimson, or dark violet.

Tissue water

Ditto.

Sulphuric acid

Darkens the color to a cochinilla red.
<table>
<thead>
<tr>
<th>Substance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphured hydrogen</td>
<td>Acts like water</td>
</tr>
<tr>
<td>Salt of tin</td>
<td>Blood-red precipitate</td>
</tr>
<tr>
<td>Chloride of tin</td>
<td>Brick-red precipitate</td>
</tr>
<tr>
<td>Acetate of lead</td>
<td>Dark violet gelatinous precipitate</td>
</tr>
<tr>
<td>Salts of the protoxides of iron</td>
<td>Very abundant violet precipitates</td>
</tr>
<tr>
<td>Copper salts</td>
<td>Violet-brown gelatinous precipitates</td>
</tr>
<tr>
<td>Chloride of mercury</td>
<td>An abundant precipitate of a brick-red color.</td>
</tr>
<tr>
<td>Nitrate of bismuth</td>
<td>Gives a light and brilliant crimson red.</td>
</tr>
<tr>
<td>Sulphate of zinc</td>
<td>Bright-red flocculent precipitate</td>
</tr>
<tr>
<td>Tartar emetic</td>
<td>An abundant precipitate of a dark cherry color.</td>
</tr>
<tr>
<td>Neutral salts of potash</td>
<td>Acts like pure water</td>
</tr>
<tr>
<td>Water of barytes</td>
<td>Dark violet-brown precipitate</td>
</tr>
<tr>
<td>Gelatine</td>
<td>Brownish-yellow gelatinous precipitate</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Brings back the liquor to a light yellow, with a</td>
</tr>
<tr>
<td></td>
<td>slight yellowish-brown precipitate, resembling</td>
</tr>
<tr>
<td></td>
<td>hydrated peroxide of iron</td>
</tr>
</tbody>
</table>

Pyroxylic spirit acts on barwood like alcohol, and the strongly colored solution behaves similarly towards re-agents. Hydrated ether almost immediately acquires an orange-red tint, rather paler than that with alcohol. It dissolves 1947 per cent. coloring principle. Ammonia, potash, and soda, in contact with powdered barwood, assume an extremely dark violet-red color. These solutions, neutralized with hydrochloric acid, deposit the coloring matter in the form of a dark reddish-brown powder. Acetic acid becomes of a dark-red color, as with saunders wood.

Barwood is but slightly soluble; but the difficulty arising from its slight solubility is, according to Mr. Napier, overcome by the following very ingenious arrangement:—The coloring matter while hot combines easily with the proto-compounds of tin, forming an insoluble rich red color. The goods to be dyed are impregnated with proto-chloride of tin combined with starch. The proper proportion of barwood for the color desired is put into a boiler with water, and brought to boil. The goods thus impregnated are put into this boiling water containing the rasped wood, and the small portion of coloring matter dissolved in the water is immediately taken up by the goods. The water, thus exhausted, dissolves a new portion of coloring matter, which is again taken up by the goods, and so on till the tin upon the cloth has become (if we may so term it) saturated. The color is then at its brightest and richest phase.

In 1855, the quantity of barwood imported, duty free, was 2,710 tons.

Of the barwood imported, 227 tons were re-exported; the computed real value of which was £1,214.

**Baryta, Carbonate Of.** The composition of the native carbonate of baryta may be regarded as baryta 77.59 and carbonic acid 22.41. It is found in Shropshire, Cumberland, Westmoreland, and Northumberland. The carbonate of baryta is employed in our color manufactories as a base for some of the more delicate colors; it is also used in the manufacture of plate-glass; and, in France, it is much used in the preparation of beet-root sugar.

<table>
<thead>
<tr>
<th>Tons.</th>
<th>cwts.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alston Moor produced, in 1856</td>
<td>443</td>
</tr>
<tr>
<td>Fallowfield (Northumberland) ditto</td>
<td>1,045</td>
</tr>
</tbody>
</table>

**Baryta, Sulphate Of.** The barry of Brooke and Miller, barytes of Dana and Phillips, Bolognian spar, called also "cawk" and "heavy spar." It is composed of baryta 65-68, sulphuric acid 34-37, with sometimes a little iron, lime, or silen.

This salt of baryta is very extensively spread over various parts of the islands. It is worked largely in Derbyshire, Yorkshire, Shropshire, and the Isle of Arran. In 1856 the production was as follows:—From

<table>
<thead>
<tr>
<th>Tons.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derbyshire</td>
</tr>
<tr>
<td>Shropshire</td>
</tr>
<tr>
<td>Lantray (Ireland)</td>
</tr>
<tr>
<td>Isle of Arran</td>
</tr>
<tr>
<td>Kirkcudbright</td>
</tr>
</tbody>
</table>

It might be obtained in very large quantities in Devonshire, Cornwall, and other places, if the demand for it sufficiently increased the price so as to render the working of it profitable. A large quantity of the ground sulphate of baryta is employed in the adulteration of white lead. Paint containing much baryta very soon washes off the surface upon which it is spread. Lead combines with the oil, and forms, indeed, a plaster. No such combination takes place between the oil and the baryta, hence they soon separate by the action of water. Baryta is employed to some extent in the pyrotechnic art, in the production of flames of a greenish character.
BATHS.

In 1856 we imported—

Baryta, sulphate (ground) - - - - - - - Tons.
And in the same year we exported—

Barytes (sulphate and carbonate) - - - 67,751 - - - £12,145

BASALT. One of the most common varieties of trap rock. It is a dark green or black stone, composed of augite and felspar, very compact in texture, and of considerable hardness, often found in regular pillars of three or more sides, called "basaltic columns." Remarkable examples of this kind are seen at the Giant's Causeway, in Ireland, and at Fingal's Cave, in Staffa, one of the Hebrides. The term is used by Pliny, and is said to come from basalt, an Ethiopian word signifying iron. The rock sometimes contains much iron.—

Lyell's Principles of Geology. Experiments have been made on a large scale to apply basaltic rock, after it has undergone fusion, to decorative and ornamental purposes. Messrs. Chance (brothers) of Birmingham, have adopted the process of melting the Rowley rag, a basaltic rock forming the plateau of the Rowley hills, near Dudley, South Staffordshire, and then casting it into moulds for architectural ornaments, tiles for pavements, &c. Not only the Rowley rag, but basalt, greenstone, whinstone, or any similar mineral, may be used. The material is melted in a reverberatory furnace, and when in a sufficiently fluid state is poured into moulds of sand encased in iron boxes, these moulds having been previously raised to a red heat in ovens suitable for the purpose. The object to be attained by heating the moulds previous to their reception of the liquid material, is to retard the rate of cooling; as the result of slow cooling is a hard, strong, and stony substance, closely resembling the natural stone, while the result of rapid cooling is a dark brittle glass.

BASILICON. The name given by the old apothecaries to a mixture of oil, wax, and resin, which is represented by the Cera. resin of the present day.

BASSORA GUM. A gum obtained from the Acacia lanceopHila, brought from Basora. It has a specific gravity of 1.3391, and is yellowish white in color.

BASKETS. Weaving of rods into baskets is one of the most ancient of the arts amongst men; and it is practised in almost every part of the globe, whether inhabited by civilized or savage races. Basket-making requires no description here.

Imports:—

In 1856 we imported of rods peeled for basket-making, 128,103 bundles, value £12,309
“ rods unpeeled “ 704,004 “ 137,146 “ 7,858
“ baskets “ - - - - - 176,720 cubic feet “ 37,560

Of these, 152,777 cubic feet were from France.

BATH METAL consists of 3 oz. of zinc to 1 lb. of copper.

BATHS. Public baths and wash-houses have now become common amongst us, and with them an increased cleanliness is apparent, and improved health throughout the population. The following is a return of the bathing and washing at the public baths and wash-houses in London, conducted under or in accordance with the Acts 9 and 10 Vict., cap. 74, and 10 and 11 Vict., cap. 51, and of a few out of the similar establishments in the country:

<table>
<thead>
<tr>
<th>Name of Establishment</th>
<th>Number of Bathers</th>
<th>Number of Washers</th>
<th>Total Receipts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metropolis.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. The Model, Whitechapel</td>
<td>156,110</td>
<td>43,589</td>
<td>£2,976 7 3</td>
</tr>
<tr>
<td>2. St. Martin's-in-the-Fields</td>
<td>155,418</td>
<td>46,257</td>
<td>3,007 5 10</td>
</tr>
<tr>
<td>3. St. Marylebone</td>
<td>155,827</td>
<td>37,061</td>
<td>2,498 2 3</td>
</tr>
<tr>
<td>4. St. Margaret and St. John, Westminster</td>
<td>111,992</td>
<td>66,644</td>
<td>2,924 12 5</td>
</tr>
<tr>
<td>5. Greenwich</td>
<td>61,782</td>
<td>8,815</td>
<td>995 11 4</td>
</tr>
<tr>
<td>6. St. James, Westminster</td>
<td>111,870</td>
<td>55,829</td>
<td>2,638 10 11</td>
</tr>
<tr>
<td>7. Poplar</td>
<td>41,400</td>
<td>10,714</td>
<td>845 15 10</td>
</tr>
<tr>
<td>8. St. Giles's and Bloomsbury</td>
<td>88,810</td>
<td>21,001</td>
<td>1,546 3 0</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>877,699</td>
<td>269,040</td>
<td>16,112 9 3</td>
</tr>
</tbody>
</table>

**Country.**

Liverpool:—

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of Bathers</th>
<th>Number of Washers</th>
<th>Total Receipts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornwalls Street</td>
<td>98,460</td>
<td>-</td>
<td>1,561 3 2</td>
</tr>
<tr>
<td>Paul Street</td>
<td>44,747</td>
<td>11,480</td>
<td>797 4 4</td>
</tr>
<tr>
<td>George's Pier-head</td>
<td>45,243</td>
<td>-</td>
<td>1,654 5 6</td>
</tr>
<tr>
<td>Hull</td>
<td>52,143</td>
<td>7,675</td>
<td>612 8 7</td>
</tr>
<tr>
<td>Bristol</td>
<td>40,262</td>
<td>11,068</td>
<td>599 11 2</td>
</tr>
<tr>
<td>Preston</td>
<td>29,296</td>
<td>10,975</td>
<td>405 10 5</td>
</tr>
<tr>
<td>Birmingham</td>
<td>98,596</td>
<td>5,547</td>
<td>1,854 14 5</td>
</tr>
<tr>
<td>Maidstone</td>
<td>31,221</td>
<td>5,773</td>
<td>348 8 10</td>
</tr>
</tbody>
</table>
BAY SALT.

The return does not include the George Street (Hampstead Road) and Lambeth establishments, which are not regulated by the public acts.

The steady increase of the revenue derived from the baths and wash-houses in London, from the commencement of the undertaking in 1846, shows the practical utility of these institutions, and their effect on the physical and social condition of the industrious classes; viz.:

The aggregate receipts of nine establishments, inclusive of the

<table>
<thead>
<tr>
<th>George Street establishment, during 1853, amount to</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1852. Eight establishments</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1851. Six establishments</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1850. Four establishments</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1849. Three establishments</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1848. Two establishments</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1847. Ditto</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1846. Ditto</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Showing an increase, in 1853 over 1846, of £15,317 0s. 7d.

These conveniences—now, indeed, become absolute necessities—are extending in every part of the country.

Baths, as curative agents, are of very different kinds. **Vapor Baths** are stimulant and sudorific; they may be either to be breathed, or not to be breathed. Dr. Pereira has given the following Table, as a comparative view of the heating powers of vapor and of water:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Not breathed</td>
</tr>
<tr>
<td>Tepid bath</td>
<td>88° to 92°</td>
<td>96° to 106°</td>
</tr>
<tr>
<td>Warm bath</td>
<td>92 °  98</td>
<td>100 ° 120</td>
</tr>
<tr>
<td>Hot bath</td>
<td>98 ° 106</td>
<td>120 ° 160</td>
</tr>
</tbody>
</table>

Local vapor baths are applied in affections of the joints, and the like.

**Vapor douche** is a jet of aqueous vapor directed on some part of the body.

**Medicated vapor baths** are prepared by impregnating vapor with the odors of medicinal plants.

Sulphur, chlorine, sulphurous acid, iodine, and camphor, are occasionally employed in conjunction with aqueous vapor.

**Warm, tepid, and hot baths** are sufficiently described above.

**BAY SALT.** The larger crystalline salt of commerce.

**BAY, THE SWEET.** (Laurus nobilis.) Bay leaves have a bitter aromatic taste, and an aromatic odor, which leads to their use in cookery.

**BAYS, OIL OF.** This oil is imported in barrels from Trieste. It is obtained from the fresh and ripe berries of the bay tree by bruising them in a mortar, boiling them for three hours in water, and then pressing them. When cold, the expressed oil is found floating on the top of the decoction. Its principal use is in the preparation of veterinary embrocations.

**BEADS.** (Grain, Fr.; Bechte, Germ.) Perforated balls of glass, porcelain, or gems, strung and worn for ornaments; or, amongst some of the uncivilized races, employed instead of money.

Glass beads have long been made in very large quantities in the glass-houses of Murano, at Venice.

Glass tubes, previously ornamented by color and reticulation, are drawn out in proper sizes, from 100 to 200 feet in length, and of all possible colors. Not less than 300 shades are manufactured at Venice. These tubes are cut into lengths of about two feet, and then, with a knife, they are cut into fragments, having about the same length as their diameter. The edges of these beads are, of course, sharp; and they are subjected to a process for removing this. Sand and wood-ashes are stirred with the beads, so that the perforations may be filled by the sand; this prevents the pieces of glass from adhering in the subsequent process, which consists in putting them into a revolving cylinder and heating them. The finished beads are sifted, sorted in various sizes, and strung by women for the market.

In the Jurors’ Report of the Great Exhibition of 1851 are the following remarks on this manufacture:—

"The old Venetian manufactures of glass and glass wares fully sustain their importance; and those of paper, jewellery, wax-lights, velvets, and laces, rather exceed their ordinary production. The one article of beads employs upwards of 5,000 people at the principal fabric on the island of Murano; and the annual value is at least £200,000. They are ex-
BEN OIL.

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ported to London, Marseilles, Hamburg, and thence to Africa and Asia, and the great Eastern Archipelago.

The perles à la lune are a finer, and, consequently, more expensive bead, which are prepared by twisting a small rod of glass, softened by a blowpipe, about an iron wire.

The preparation and cutting of gems into beads belong especially to the lapidary. The production of beads of Paste, and of artificial Pearls, will be noticed under those heads respectively.

In India beads of rock crystal are often very beautifully cut.

Dr. Gilchrist states:—Coral beads are in high estimation throughout Hindostan for necklaces and bracelets for women. These beads are manufactured from the red coral fished up in various parts of Asia; they are very costly, especially when they run to any size; and they are generally sold by their weight of silver.

Coral beads were always favorite articles for ornament even in this country; and in the "Illustrations of Manners and Experiences of antient Times in England," by Nicholls, 1798, we find the following entries from "the churchwardens' account of St. Mary Hill, London," containing "the inventory of John Port, layt the king's servant, as after followeth:"

- Item of other old gear found in the house:— £ 5. 4. d.
- Item one oz. and ½ of corall:— 0 2 6
- Jewels for her body:—
- Item, a pair of coral beads, gaudyed with gaudy of silver and gilt, 10 oz. at 8s. 4d. 1 13 4.

(John Port died 1524.)

We imported, in 1835, of coral beads, 2,279 lbs., and of jet beads, 9 lbs.; while of other kinds unenumerated, 14,251 lbs. were brought into the United Kingdom.

In addition to these, the following were our Imports of glass beads and bugles:

<table>
<thead>
<tr>
<th>Country</th>
<th>Lbs.</th>
<th>Computed real value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>8,889</td>
<td>1,111</td>
</tr>
<tr>
<td>Hanse Towns</td>
<td>541,580</td>
<td>67,697</td>
</tr>
<tr>
<td>Holland</td>
<td>37,448</td>
<td>4,681</td>
</tr>
<tr>
<td>Belgium</td>
<td>26,794</td>
<td>3,213</td>
</tr>
<tr>
<td>France</td>
<td>6,835</td>
<td>854</td>
</tr>
<tr>
<td>Sardinia</td>
<td>16,949</td>
<td>947</td>
</tr>
<tr>
<td>Tuscany</td>
<td>10,432</td>
<td>622</td>
</tr>
<tr>
<td>Austrian Italy</td>
<td>1,496,453</td>
<td>74,973</td>
</tr>
<tr>
<td>Other parts</td>
<td>14,906</td>
<td>1,594</td>
</tr>
</tbody>
</table>

2,157,593         £155,262

We exported, in 1856, ornamental beads to the value of £21,504.

BEAVER, THE. (Castor Fiber) This animal is captured for its skin, and for the castor (castoreum,) which is employed medicinally. See Fris.

BEHRINE, or BEEBEERINE. (CO2HPNO2.) An alkali discovered by Dr. Rodic, of Demerara, in the bark of the bebeerine tree. It was examined more minutely by Madagan and Tilley, and still more recently by Von Planta, who has determined its true formula. It is very bitter, and highly febrifuge.

BEECH. (Ficus communis, Fr.; Gemeine Buche, Germ.) The beech tree (the Fagus sylvatica of Linnæus) is one of the most magnificent of the English trees, attaining, in about sixty or seventy years in favorable situations, a height of from 70 to 100 feet, and its trunk a diameter of five feet. The wood, when green, is the hardest of British timbers, and its durability is increased by steeping in water; it is chiefly used by cabinet-makers, cooper, coach-builders, and turners. A substitute for olive oil has been extracted from beech nuts.

BELLADONNA. (Belledone, Fr.) The Atropa Belladonna, or deadly nightshade.

BELL-METAL ORE. Sulphide of Tin. (Elain sulphuré, Haüy; Zinnkies, Hausmann.)

The composition of the ordinary variety of this ore is,

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>30.0</td>
</tr>
<tr>
<td>Iron</td>
<td>12.0</td>
</tr>
<tr>
<td>Tin</td>
<td>26.5</td>
</tr>
<tr>
<td>Sulphur</td>
<td>30.5</td>
</tr>
</tbody>
</table>

It is found in many of the Cornish mines, and especially at those of Car A Bere.

BEN NUTS. (Ben noix, Fr.; Salonnase, Germ.) The tree which furnishes these nuts is the Guitandina moringa of Linnæus, a native of India, Ceylon, Arabia, and Egypt.

BEN OIL. The oil of ben, which may be obtained from the decorticated nuts, is said to be far less liable than other oils to become rancid, and hence it is much used by watch-
BENZOIC ACID. (C\textsubscript{6}H\textsubscript{5}O\textsubscript{2}.) This acid may be obtained by placing benzoil powdered with sand in an evaporating basin, and above it a paper cap; on applying heat carefully to the sand, acid vapors arise from the resin, and they are deposited in the form of fine light crystals with the paper cap. Stolz recommends the following process for extracting the acid:—The resin is to be dissolved in three parts of alcohol, the solution is to be introduced into a retort, and a solution of carbonate of soda dissolved in dilute alcohol is to be gradually added to it, till the free acid be neutralized; and then a bulk of water equal to double the weight of the benzoil is to be poured in. The alcohol being drawn off by distillation, the remaining liquid contains the acid, and the resin floating upon it may be skimmed off and washed, when its weight will be found to amount to about 80 per cent. of the raw material. The benzoil contains traces of a volatile oil, and a substance soluble in water, at least through the agency of carbonate of potash. There are several other methods for obtaining benzoic acid, described in Ure’s “Dictionary of Chemistry.” Benzoic acid has no special use in the arts.

BENZOLE. Syn. Benzine, benzene, benzol, hydruret of phenyle, (C\textsubscript{6}H\textsubscript{5}.) The more volatile portion of coal naphtha has been shown by Mansfield to consist chiefly of this substance. It is produced in a great number of reactions in which organic bodies are exposed to high temperatures. It may at once be obtained in a state of purity by distilling benzoic acid with excess of quicklime. The lime acts by removing two equivalents of carboxylic acid from the benzoic acid. The method of obtaining benzoil from coal naphtha will be found fully described under the head of Nitrobenzole. Benzole is also contained in considerable quantity in bone oil; but it is accompanied by peculiar nitrogenised volatile fluids, which are difficult of removal. The latter, owing to their powerful and fetid odor, greatly injure the quality of the bone-oil benzole. Benzoil is an exceedingly volatile fluid, boiling at ordinary pressures at 187° F. Its density is 0.850. Owing to the levity of benzole being regarded by manufacturers as a proof of its purity, it is not uncommon to find it adulterated with the naphtha from the Torvanehill coal. Benzole is also contained in the carbonization of boghead coal, which has a density as low as 0.750. Any benzoil having a lower density than 0.850 is impure. Benzole is excessively inflammable, and its vapor mixed with air is explosive. Numerous lives have been lost owing to these properties, among them that of Mr. Mansfield, to whom we are indebted for an excellent investigation on coal naphtha. Benzole is greatly used in commerce, owing to its valuable solvent properties. It dissolves caoutchouc and gutta percha readily, and, on evaporation, leaves them in a state well adapted for water-proofing and many other purposes. Its power of dissolving fatty, oily, and other greasy matters, has caused it to become an article of commerce under the name of benzoline. It readily extracts grease even from the most delicate fabrics, and, as it soon, on exposure to the air, evaporates totally away, no odor remains to betray the fact of its having been used. It dissolves readily in very strong nitric acid, and, on the addition of water, it is precipitated as a heavy oil, having the composition C\textsubscript{6}H\textsubscript{5}NO\textsubscript{3}. The latter compound is nitrobenzole; it is regarded as benzole in which one equivalent of hydrogen is replaced by hypochloric acid. Nitrobenzole, in a state of tolerable purity, is a pale-yellow oil, having a sweetish taste, and an odor greatly resembling bitter almonds. Owing to its comparative cheapness, it is employed in perfumery. Nitrobenzole can be prepared with nitric acid of moderate strength, such as is ordinarily obtained in commerce; but it then becomes necessary to distill the acid and the hydrocarbon together several times. The product so obtained is darker in color, and in other respects inferior to that obtained with highly concentrated acid. By treatment with acetate of protodize of iron, nitrobenzole becomes transformed into aniline. This change may be effected, but far less conveniently, by means of sulphide of ammonium. Benzole is extremely valuable in many operations of manufacturing chemistry. It dissolves several alkaloids, and, on evaporation, leaves them in a state of purity. It dissolves quinine, but not cinchona, and may therefore be employed as a means of separation. Morphia and strychnine are also dissolved by it, but not in great quantity. To obtain many natural alkaloids existing in plants, it is merely necessary to digest the dry extract with caustic potash and then with benzole. The latter is to be decanted, and then distilled off on a water-bath. The alkali will be left behind in a state well adapted for crystallization or other means of purification. Benzole is becoming much used as a solvent in researches in organic chemistry. Many substances, such as chrysene and bichloride of naphthaline, crystallize better from benzole than from any other solvent.

Benzole may be employed in many ways for illuminating purposes. It is so easily inflammable that great care is necessary in using it. It does not require a wick to enable it to burn. If poured even on an inflammable surface and a light be applied, it takes fire like a train of gunpowder, and burns with a brilliant flame, emitting dense clouds of smoke, which, soon condensing into soot, presently fall in a shower of blacks. Even on the sur-
face of water it burns as freely as anywhere else. If a droachm or two be poured on water contained in a pan, and a pellet of potassium be thrown in, the benzole inflames, and rises in a column of flame of considerable height. A method of destroying enemies' shipping has been founded on this principle. In consequence of the smoky nature of the flame of benzole, (caused by the comparatively larger percentage of carbon,) it is often convenient to burn a mixture of one volume of benzole and two volumes of alcohol. A stream of air driven through benzole becomes so inflammable as to serve for the purpose of illumination. For this mode of using the hydrocarbon, it should be kept slightly warm to assist its vaporisation. A machine on this principle, of American invention, has been employed to illuminate theatres. The air is driven through the benzole by a very simple contrivance, the motive power being a descending weight.

When quite pure, benzole freezes at 82° to a beautiful snow-white substance, resembling camphor. The mass retains a solid form until a temperature of 40° or 41° is reached. This property of solidifying under the influence of cold may be made use of to produce pure benzole from the more volatile portion of coal naphtha. To obtain it perfectly pure, it should be frozen at least three times, the portion not solidifying being removed by filtration through calico. The unfrozen portion contains hydrocarbons, homologous with olefiant gas.

Benzole dissolves free iodine and bromine, and has even been used in analysis to separate them from kelp and other substances containing them. They must of course be set free before acting with the hydrocarbon. The presence of benzole in mixtures may easily be demonstrated, even when present in very small quantity, by converting it into aniline, and obtaining the characteristic reaction with chloride of lime. For this purpose the mixture is to be dissolved in concentrated nitric acid and the nitrobenzole precipitated by water. The fluid is then agitated with ether, which dissolves the nitrocompound. The ethereal solution is mixed with an equal bulk of alcohol and hydrochloric acid: a little granulated zinc being added, hydrogen is evolved, and, by acting in a nascent state on the nitrocompound, reduces it to the state of aniline. The base is then to be separated by an excess of potash, and the alkaline fluid is shaken with other to dissolve the base. The ethereal fluid being evaporated, leaves the aniline. On adding water and then a few drops of solution of chloride of lime, the purple color indicative of aniline is immediately produced. (Hofmann.) The writer of this article has by this process detected minute traces of benzole in mixtures consisting almost entirely of homologues of olefiant gas.—C. G. W.

BERGAMOT. (Bergeronate, Fr.) The Citrus Bergamia, a citrus cultivated in the centre and south of Europe. By distillation from the rind of the fruit is obtained the well-known essence of bergamot. This essential oil and the fruit are principally obtained from Florence and Portugal. See Oils, Essential.

BERGAMOT. A coarse tapestry, said to have been invented at Bergamo, in Italy, made of ox and goats' hair, with cotton or hemp.

BERRY. The term is commonly applied, not only to small fruit, but in some cases to seeds. The following is Professor Lindley's definition of a berry:—"A succulent or pulpy fruit containing naked seeds, or, in more technical language, a succulent or pulpy pericarp, or seed-vessel without valves, containing several seeds, which are naked, that is, which have no covering but the pulp and rind. It is commonly round or oval. But in popular language, berry extends only to smaller fruits, as strawberry, gooseberry, &c., containing seeds or granules. An indelible pulpy pericarp, many-celled and many-seeded; the attachment of the seeds lost at maturity, and the seeds remaining scattered in the pulp." Berries are used in some of the processes of manufacture, but they are not of much importance.

Bay Berries.—The fruit of the Larus nobilis, or the sweet bay. Both the leaves and the fruit are employed as flavorings. A volatile oil, the oil of sweet bay, is obtained by distillation with water; and a fixed oil, by bruising the berries, and boiling them for some hours in water; this oil, called also Laurel fat, is imported from Italy.

Turkey Yellow Berries.—The unripe fruit of the Rhamnus infectorius. They are used in calico-printing, producing a lively but fugitive yellow color.

Persian Yellow Berries.—These are said to be produced by the same species of plant; but the color is considered more permanent, and they fetch higher prices.

Berries of Avispón.—Another name given to the Turkey and Persian berries.

Juniper Berries.—The fruit of the Juniperus communis. They are chiefly used for flavoring gin and some spirituous cordials, and in the preparation of some pharmaceutical articles, as the oil of juniper and the compound spirits of juniper.

Bear Berry.—The fruit of the Uva Ursi. The leaves only are used medically.
**BEYRIL.**

The Portuguese of Para have for a long time driven a great trade with the nuts of this tree, which the natives call *Juaria*, and the Spaniards *Almendra*. They send cargoes to French Guiana, whence they are shipped for England and Lisbon. The kernels yield a large quantity of oil well suited for lamps.—*Humboldt and Bonpland*.

**BEYRIL.** (Beryl, Fr.; Beryl, Germ.; Smaragd, Ital.) A beautiful mineral or gem, usually of a green color of various shades, passing into honey yellow and sky blue. Beryl and emerald are varieties of the same species, the latter including the rich green transparent specimens which owe their color to oxide of chrome; the former those of other colors produced by oxide of iron. Gmelin gives the composition of beryl as:

<table>
<thead>
<tr>
<th>Silica</th>
<th>Alumina</th>
<th>Glucine</th>
<th>Red oxide of iron</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.24</td>
</tr>
</tbody>
</table>

"Beryls of gigantic size have been found in the United States, at Aeworth and Grafton, New Hampshire, and Royalton, Mass. One beryl from Grafton weighs 2,900 lbs.; it is 32 inches through in one direction, and 23 in another transverse, and is 4 feet 3 inches long. Another crystal from this locality, according to Professor Hubbard, measures 45 inches by 24 in its diameters, and a single foot in length, by calculation, weighs 1,075 lbs., making it, in all, nearly 24 tons. At Royalton, one crystal exceeded a foot in length."—*Dana*.

**False Beryls of Commerce.** Some of the natural crystals of phosphate of lime are introduced as beryls. The *Saxony beryl*. *The Chrystolite*, known by the Germans as the *Pierre d'Asperge*, is also sold as the beryl. Fluor spar of different colors are sold as false beryl, false emeralds, false amethysts, and false topazes. These are fluate of lime.

**BELTEL.** A compound, in universal use in the East, consisting of the leaf of the betel-pepper, with the betel-nut, a little catechu, and some chumam, (lime obtained by calcining shells.) This is almost universally used throughout central and tropical Asia; the people are unceasingly masticating the betel.

**BELTEL-LEAF.** The leaf of the pepper vine, *Piper betel.* This plant is extensively cultivated throughout tropical Asia, and forms a large and important article of Eastern traffic.

**BELTEL-NUT, or ARECA.** The fruit of the *Areca catechu*, which is eaten both in its ripe and its unripe state.

**BEYREYL.** A mining term, signifying a flowing stream. It is applied by the miners to any portion of a lode or of the rock which is impregnated with tin.

**BEZOAR.** (The most probable etymology of the word is from the Persian *Pudaler*, i. e. expelling poison.—*Penny Cyclopaedia*.) A concretion found in the stomach of animals of the goat kind; it is said to be especially produced by the *Capra gazella*. The finest bezoar is brought from India by Borneo and the shores of the Persian Gulf. The *Capra Lycaena*, or wild goat of Persia producing this concretion, which, by way of commerce, was called the *Lapis bezoar orientalis*. The bezoars, which were supposed to cure all diseases, have been found, by the analysis of Fourrey and Vaquetin and of Proust, to be nothing more than some portions of the food of the animal agglutinated into a ball with phosphate of lime.

**Fossil bezoar** is found in Sicily, in sand and clay pits. They are concretions of a purple color around some, usually organic, body, and the size of a walnut. Fossil bezoar is sometimes called *Sicilian earth*; and it appears to be of a similar character to Armenian balsam.

**Bicarbonate of Lime.**—An old preparation of the oxide of antimony.

**Bicarbonate of Potash.**—There are several modes of converting the carbonate into bicarbonate. The most economical is by exposing the salt to a current of carbolic acid. For this purpose some manufacturers place it, slightly moistened, on stone ware trays, and allow the vapors of burning coke to travel slowly over it. The sources of the gas used in this manufacture will vary according to the locality in which it is undertaken. It is not unusual to produce it by the action of sulphuric acid on limestone. The gas generated in this fermentation has been employed, and even that which in some places issues from the earth. The bicarbonate of potash is far less soluble than the carbonate, as it requires four parts of cold water for solution, whereas the carbonate dissolves in 0.9 of its weight of water at 54°. Consequently, if a strong solution is saturated with carbonate, the bicarbonate crystallizes out. When common pearl ashes are dissolved in water, and the gas is passed in, a large quantity of a white precipitate is often thrown down; it consists chiefly of silica, but often contains alumina and other matters. Considerable heat is developed when moistened
carbonate of potash is exposed to a current of carbonic acid gas. When carbonate of potash is dissolved in water, and gradually treated with acetic acid, so as to form acetate of potash, by no means the whole of the carbonic acid is expelled, and a point is arrived at when a considerable quantity of crystals is deposited; they consist of very pure bicarbonate of potash. In making acetate of potash on the large scale, the quantity of crystalline precipitate obtained in this manner is sometimes very large. Bicarbonate of potash is usually perfectly pure. If well crystallized, all the impurities remain in the mother-liquor, and on heating to redness almost exactly 94% of the theoretical amount of residue is left, viz. 69.06 per cent. Crystallized bicarbonate of potash always contains one equivalent of water, its formula being $\text{KO, } 2\text{CO}_2 + \text{H}_2\text{O}$.

**Bicarbonate of Soda.**—This salt is obtained by the same methods as the salt of potash. The crystals have a corresponding formula to the potash salt; namely, $\text{NaO, } 2\text{CO}_2 + \text{H}_2\text{O}$. It requires about 13 parts of water at 60° to dissolve it. When pure, 190 parts weigh 63.18 of $\text{NaO, } 2\text{CO}_2$ on ignition.

The bicarbonates of potash and soda lose carbonic acid by the boiling of an aqueous solution.

Modern theoretical chemists regard carbonic acid as being blassie, the true formula being $\text{CO}_2$, instead of $\text{CO}_3$. There can be little doubt that this view is the correct one, and it has the advantage of explaining why the bicarbonates are neutral instead of acid salts. Moreover, $\text{CO}_2$ corresponds to 4 volumes, like organic substances generally; whereas, if we assume $\text{CO}_3$ as one atom of the gas, we are compelled to admit a 2-volume formula.—

C. G. W.

**BIDERY.** An Indian alloy of considerable interest, named Bidery from Bider, a city X. E. of Hyderabad. Many articles are made, remarkable for elegance of form and for gracefully-engraved patterns. Although the groundwork of this composition appears of a blackish color, its natural tint is that of pewter or zinc.

Dr. Heyne says it is composed of, copper, 16; lead, 4; tin, 2; and to every 3 ounces of alloy, 16 ounces of spelter (that is, of zinc) are added, when the alloy is melted for use. To give the esteemed black color and to bring out the pattern, it is dipped in a solution of sal ammoniac, saltpetre, common salt, and blue vitriol. Dr. Hamilton saw zinc, 12,500 grains; copper, 400; and lead, 414; melted together under a mixture of resin and bees' wax introduced into the crucible to prevent calcination; it was then poured into moulds of baked clay, and the articles handed over to be turned in a lathe.

Though called bidery, and sometimes vidry, it is manufactured in other places. In some parts of the Nizami's dominions, specimens were obtained, for the Exhibition of 1851, of great beauty. Bidery does not rust, yields little to the hammer, and breaks only when violently beaten. According to Dr. Hamilton, bidery is not nearly so fusible as zinc or tin, but melts more easily than copper.—*Dr. Royle, Lecture on the Great Exhibition.*

**BJOUTRY.** (Bijouterie, Fr.) Jewellery.—the manufacture of and dealing in jewellery. This work is not the place in which to describe the almost endless variety of articles which come under this denomination. The principal places for the manufacture, in England, are Birmingham and London. The trade in jewellery forms one of the most important branches of French commerce; on which a French writer says:—"La bijouterie est une des branches les plus importantes du commerce français, et c'est elle qui constate, de la manière la plus évidente, notre supériorité dans les arts du dessin et les progrès toujours croissants de l'industrie Parisienne. Dans cette partie essentielle, elle n'a pas de rivaux, et elle rend tributaire de notre pays presque toute l'Europe, et une grande partie de l'Asie et de l'Amérique."

The ordinary practice has been to divide articles of this character into two principal kinds,—fine jewellery, and false jewellery, (*bijoutier en fin et bijoutier en faux*.) Another division, among the French jewellers especially, has been to adopt four classes: 1, fine jewellery, which is all gold; 2, silver jewellery; 3, false jewellery; and, 4, jewellery of steel or iron.

**BISCUITS.** The manufacture of fancy biscuits, which in former times was confined to the pastry-cook and confectioner, has of late years assumed considerable importance, and several firms are now exclusively engaged in this branch of industry, the products of which are sold under an extraordinary variety of names. Some of these, namely, the "plain biscuit, arrow-root, captain, brown meal, cinnamon, caraway, vanilla biscuits," &c., are intelligible enough; but, if we except "Abernethy biscuit, macaroons, and cracknels," with the names of which the public, from long usage, are familiar, the rest of the products of the modern biscuit maker, "Africans, Jamaica, Queen's routes, ratafias, Bath and other sorts of olivers, exhibition, rings and fingers, pie-nies, cudly," &c., &c., forms a list of upwards of eighty familiar names, all expressive of articles of different form, appearance, and taste, made of nearly the same materials, with but little variation in the proportion in which they are used,—the principal ingredients in all being flour and water, butter, milk, eggs, and caraway, nutmeg, cinnamon, or mace, or ginger, or essence of lemon, acroll, or orange-
flower water, called, in technical language, "flavorings." The kneading of these materials is always performed by a kneading or mixing machine. The dough or paste produced is passed several times between two revolving cylinders adjusted at a proper distance so as to obtain a flat, perfectly homogeneous mass, slab, or sheet. This is transferred to a stamping or cutting machine, consisting of two cylinders, through which the sheet of homogeneous paste has to pass, and by which it is laminated to the proper thickness, and at the same time pushed under a stamping and docking frame, which cuts it into discs, or into oval or otherwise shaped pieces, as occasion may require. The stamps or cutters in the frame being internally provided with prongs, push the cut pieces of dough, or raw cakes, out of the cutting frame, and at the same time dock the cakes, or cut pieces, with a series of holes, for the subsequent escape of the moisture, which, but for these vents, would distort and spoil the cake or biscuit when put in the oven. The temperature of the oven should be so regulated as to be perfectly uniform, neither too high nor too low, but just at such a heat as is sufficient to give the biscuits a light brown color. For such a purpose the hot water oven of Mr. Perkins, or that of Dr. Roland, is the best that can possibly be used. (See Bread.) Roland's oven offers the peculiar advantage that, by turning the screw, the sole of the oven can be brought nearer to the top, and a temperature is thus obtained suitable for baking thoroughly, without burning, the thinnest cakes.

One of the most curious branches of the baker's craft is the manufacture of gingerbread, which contains such a proportion of molasses that it cannot be raised by means of yeast. Its ingredients are flour, molasses or treacle, butter, common potatoes, and alum. After the butter is melted, and the potashes and alum are dissolved in a little hot water, these three ingredients, along with the treacle, are poured among the flour which is to form the body of the bread. The whole is then incorporated by mixture, and kneading into a stiff dough. Of these five constituents the alum is the least essential, although it makes the bread lighter and crispier, and renders the process more rapid; for gingerbread, dough requires to stand over for several days, some 8 or 10, before it acquires the state of porosity which qualifies it for the oven; the action of the treacle and alum on the potashes, in evolving carbonic acid, seems to be the gassifying principle of gingerbread; for if carbonate of potash is withheld from the mixture, the bread, when baked, resembles, in hardness, a piece of wood.

Treacle is always acidulous. Carbonate of magnesia and soda may be used as substitutes for the potashes. Dr. Colquhoun has found that carbonate of magnesia and tartaric acid may replace the potashes and the alum with great advantage, affording a gingerbread fully more agreeable to the taste, and much more wholesome than the common kind, which contains a notable quantity of potashes. His proportions are: 1 lb. of flour, ½ of an ounce of carbonate of magnesia, and ½ of an ounce of tartaric acid, in addition to the treacle, butter, and aromatics, as at present used. The acid and alkaline earth must be well diffused through the whole dough; the magnesia should, in fact, be first of all mixed with the flour. The melted butter, the treacle, and the acid dissolved in a little water, are poured all at once amongst the flour, and kneaded into a consistent dough, which being set aside for half an hour or an hour, will be ready for the oven, and should never be kept unbaked for more than 2 or 3 hours. The following more complete recipe is given by Dr. Colquhoun for making thin gingerbread cakes:-Flour 1 lb., treacle ½ lb., raw sugar ½ lb., butter 2 ounces, carbonate of magnesia ½ ounce, tartaric acid ¼ ounce, ginger ½ ounce, cinnamon ½ ounce, nutmeg 1 ounce. This compound has rather more butter than common thin gingerbread. In addition to these, yellow ochre is frequently added by cheap gingerbread-makers, and altogether this preparation, more generally consumed by children, is very objectionable.

"Puff-paste" is a preparation of flour and butter, which is in great demand not only at the pastry-cooks', but in almost every private family. Take a certain quantity of flour, say half a pound, put it upon a wooden board, make a hole or depression in the centre, and mix it with somewhat less than half a pint of cold water, so as to make a softish paste; dry it off from the board by shaking a little flour over and under, as is well known, but do not "work it" more than you can help. Take now a quarter of a pound of fresh butter, which should be as hard as possible, (and therefore it should be kept in as cold a place as practicable, the ice closet, if procurable, being the best place,) and squeeze out all the water, or buttermilk which it contains, by kneading it with one hand on the board. This operation is called in French "mouliner le beurre." Roll now the paste prepared as above into a flat, thick, square slab, extending about 6 or 7 inches; lay the pat of butter, treated as above, in the middle of the slab of paste, and so wrap the butter up into it by folding the sides of the paste all round over it; roll the whole mass gently with the rolling-pin, so as to form a thick sheet, put it upon a tin plate, or tray, cover it with a linen cloth wetted with water as cold as possible, and leave the whole at rest for about a quarter of an hour in a cold place. When the mass with the rolling-pin in it is a sheet about 15 or 16 inches long, and fold it into three, one over the other; roll it out again into a sheet as before, and again fold it into three, one over the other, as before, and repeat this operation...
BISMUTH. 141

once more, making three times in all. Put the square mass, with a wet cloth upon it, in a cold place for another quarter of an hour, as before, and at the end of that time roll it out with the rolling-pin, and fold it into three, one over the other, as above; and do this once more, making five times in all, after which the paste is ready for use. Care must be taken, during the rolling, continually to dust the board and the paste with a little flour, to prevent sticking. The paste may now be placed in the dish, or tin, in which it is to be baked, taking care to cut the protruding edges with a pointed and sharp knife, so as to leave the paste all round with a clean cut edge, for otherwise it will not puff up or swell. The thick edges of pies and tarts are made by cutting strips of the paste with the knife, and carefully laying them on all round, taking care to leave the edges quite sharp. The prepared articles are then put in an oven, previously brought to a good heat, and the elastic vapor disengaged from the butter and water will at once cause the paste to swell into parallel layers of great tenacity, and apparently light, but really very heavy, since each of these thin laminae is compact and distinct. Pull-paste is indigestible. It is essential to the success of the operation, that the floor of the oven should be hot.—A. N.

BISMUTH. (Bismuth, Fr.; Bismuth, Germ.) The following are the principal ores of bismuth; the first is the source of the metal used in the arts:

Bismuth, Native, is white, with a faint reddish tinge, and a metallic lustre which is liable to tarnish. Break, silver-white. Hardness, 2 to 2.5; specific gravity, 9.727. It is brittle when cold, but slightly malleable when heated. It generally occurs in a dendritic form. It fuses readily at 476°F. Beautiful crystals can be formed artificially by fusion and subsequent slow cooling.

Native bismuth has been found associated with other minerals: in Cornwall, at Huel Sparman, near Redruth, when that mine was worked; at Trugoe Mine, near St. Columb, (Gregg.) and at the Consolidated Mines, St. Ives, Caldebeck Fells, in Cumberland, with ores of cobalt.

Bismuthine, or sulphuret of bismuth, occurs either in acicular crystals, or with a foliated, fibrous structure. It is isomorphous with stibnite. Hardness, 2 to 2.5; specific gravity, 6.4 to 6.9. It is composed of bismuth, 81.6; sulphur, 18.4. It fuses in the flame of a candle.

Bismuthine occurs in Cornwall, at Botallack, and associated with tin at St. Just, and with copper at the mines near Redruth and Camborne.

Bismuth Ochre. — A dull earthy mineral, found in the Royal Restormel Iron Mine, and in small quantities in the parish of Roach, in Cornwall. Its composition is stated by Lamplius to be:

- Oxide of bismuth
- Oxide of iron
- Carbonic acid
- Water

Tetradymite Bismuth.—Tetradymite, —occurs in Cumberland, at Brandy Gill, Carrock Fells, (Gregg.) Its composition is:

- Bismuth
- Tellurium
- Sulphur
- Selenium

Acicular Bismuth.—Alkinité—called also Needle Ore, and the plumbo-cuprous fibrous sulphide of bismuth—is composed of sulphur, 16; bismuth, 84.62; lead, 85.89; copper, 11.72.

Carbonate of Bismuth.—Bismutite. This ore is composed of a mechanical mixture of the carbonates of bismuth, of iron, and of copper.

Cuprous Bismuth.—Tannite, is sulphur, 18.88; bismuth, 62.16; copper, 18.72. This metal is also found associated with selenium and tellurium.

Bismuth may be regarded as the most remarkable of the dia-magnetic bodies, standing, indeed, at the head of the class, in the same way as iron does at the head of the magnetic order of substances.*

In Ure's "Dictionary of Chemistry" will be found various methods for the determination of bismuth. The following processes, however, appear so useful as to warrant their insertion in this place:—To detect small quantities of lead in bismuth, or in bismuth compounds, Chapman brings the somewhat flattened head, reduced before the blowpipe, in contact with some moist basic nitrate of teroxide of bismuth, when, in a short time, in consequence of the reduction of the bismuth by the lead, arborescent sprigs of bismuth are formed around the test specimen. Since zinc and iron interfere with this reaction, they must be previously removed, the former by fusion with soda, the latter with soda and borax, in the reducing flame.

* Consult De la Rive's Treatise on Electrolysis, translated by Charles V. Walker, P. R. S.
Lead and bismuth can easily be quantitatively separated from each other by the following method, proposed by Ulghren. — The solution of the two metals is precipitated by carbonate of ammonia, and the carbonates are then dissolved by acetic acid, and a blade of pure lead, the weight of which is ascertained beforehand, is plunged in the solution. This blade must be completely immersed in the liquor. The vessel is then corked up, and the experiment is left for several hours at rest. The lead precipitates the bismuth in the metallic form. When the whole of it is precipitated, the blade of lead is withdrawn, washed, dried, and weighed. The bismuth is collected on a filter, washed with distilled water which has been previously boiled, and cooled out of contact of the air; this metal is then treated with carbonate of ammonia, and the precipitate which is left, after washing and ignition, is then weighed. The total loss of the metallic lead employed indicates how much oxide of lead must be subtracted from the total weight of the protoside of lead obtained.—

E. Peligre's Edition of Rose.

Oxide of bismuth can be separated, by means of sulphhydric acid, from all the oxides which cannot be precipitated from an acid solution by this reagent. Yet, when the precipitate of sulphide of bismuth is intended to be made by means of sulphhydric acid, it is necessary to take care to dilute with water the solution of the oxide of bismuth. But as the solutions of bismuth are rendered milky by water, acetic acid should first be added to the liquor, which prevents its becoming turbid when water is poured into it. — Rose.

BITTER PRINCIPLE. (Amer. Fr.; Bitterstoff, Germ.) The “bitter principles” consist of bodies which may be extracted from vegetable productions by the agency of water, alcohol, or ether. These are not of much importance in the arts, with a few exceptions.

Lupulin.—For example, the bitter principle of the hop is used for preserving beer. It is a reddish-yellow powder, obtained from hops by digestion in alcohol, which is evaporated; then the extract is dissolved in water, and the fluid saturated with lime. This is evaporated, and the residuary mass treated with alcohol or ether.

Quassia is the bitter principle of quassia; Aalinthin, that of wormwood; and Gentianin, that of gentian, &c.

BITUMEN, or ASPHALTUM. Bitumen comprises several distinct varieties, of which the two most important are asphaltum and naphtha.

Asphaltum is solid, and of a black, or brownish-black, color, with a conchoidal brilliant fracture.

Naphtha.—Liquid and colorless when pure, with a bituminous odor.

Bitumen is the earthy, or sluggo mineral pitch—petroleum—a dark-colored fluid variety, containing much naphtha, and maltha, or mineral tar.

Bitumen in all its varieties was known to the ancients. It was used by them, combined with lime, in their buildings. Not only do we find the ruined walls of temples and palaces, in the East, with the stones cemented with this material, but some of the old Roman castles in this country are found to hold bitumen in the cement by which their stones are secured. At Agrigentum it was burnt in lamps, and called “Sicilian oil.” The Egyptians used it for embalming.—Donna.

Springs of which the waters contain a mixture of petroleum, and the various minerals allied to it—as bitumen, asphaltum, and pitch—are very numerous, and are, in many cases, undoubtedly connected with subterranean heat, which sublimes the more subtle parts of the bituminous matters contained in rocks. Many springs in the territory of Modena and Poma, in Italy, produce petroleum in abundance; but the most powerful perhaps yet known are those of Irawadi, in the Burman empire. In one locality there are said to be 520 wells, which yield annually 40,000 hogheads of petroleum.

Fluid bitumen is seen to ooze from the bottom of the sea on both sides of the island of Trinidad, and to rise up to the surface of the water. It is stated that, about seventy years ago, a spot of land on the western side of Trinidad, nearly half-way between the capital and an Indian village, sank suddenly, and was immediately replaced by a small lake of pitch. In this way, probably, was formed the celebrated Great Pitch Lake. Sir Charles Lyell remarks:—“The Orinoco has for ages been rolling down great quantities of woody and vegetable bodies into the surrounding sea, where, by the influence of currents and eddies, they may be arrested and accumulated in particular places. The frequent occurrence of earthquakes, and other indications of volcanic action in those parts, lend countenance to the opinion that these vegetable substances may have undergone, by the agency of subterranean fire, those transformations or chemical changes which produce petroleum; and this may, by the same causes, be forced up to the surface, where, by exposure to the air, it becomes inspissated, and forms the different varieties of pure and earthy pitch, or asphalten, so abundant in the island.”

The Pitch Lake is one and a half miles in circumference; the bitumen is solid and cold near the shores, but gradually increases in temperature and softness towards the centre, where it is boiling. The solidified bitumen appears as if it had cooled, as the surface boiled, in large bubbles. The ascent to the lake from the sea, a distance of three-quarters of a
miles, is covered with a hardened pitch, on which trees and vegetables flourish; and about Point la Braye, the masses of pitch look like black rocks among the foliage: the lake is underlaid by a bed of mineral coal.—Manross, quoted by Dana.

The Earl of Dundonald remarks, that vegetation contiguous to the lake of Trinidad is most luxuriant. The best pine-apples in the West Indies (called black pines) grow wild amid the pitch.

Asphaltum is abundant on the shores of the Dead Sea. It occurs in some of the mines of Derbyshire, and has been found in granite, with quartz and flint spar, at Polidice, in Cornwall. There is a remarkable bituminous lime and sandstone of the region of Bechel-brown and Lobsann, in Alsace. From the observations of Daubree, we learn that probably this bitumen has had its origin as an emanation from the interior of the earth; and indeed, in Alsace, with the great elevated fissure of the sandstone of the Vosges, a fissure which was certainly open before the deposit of the Trias, but was not yet closed during the tertiary epoch, affording during this latter, moreover, an opportunity for the deposition of spathic iron ore, iron pyrites, and heavy spar.—Annalees des Mines.

Elastic Bitumen, called also mineral caoutchouc and elastite, was first observed in Derbyshire, in the forsaken lead mine of Odin, by Dr. Lister, in 1773, who called it a subterranean fungus. It was afterwards described by Hatchett. The analysis of this variety, by Johnston, gave the following as its composition:—

<table>
<thead>
<tr>
<th>Component</th>
<th>English</th>
<th>French</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>5.0286</td>
<td>5.0286</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.0749</td>
<td>0.0749</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.0015</td>
<td>0.0015</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.0011</td>
<td>0.0011</td>
</tr>
</tbody>
</table>

Of ordinary bitumen, we have analyses of two specimens: one by Ebelmen, who obtained his sample from the Auvergne; and the other by Boussingault, which was a Peruvian specimen:—

<table>
<thead>
<tr>
<th>Component</th>
<th>Auvergne</th>
<th>Peruuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>76.13</td>
<td>88.63</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>9.41</td>
<td>9.69</td>
</tr>
<tr>
<td>Oxygen</td>
<td>10.34</td>
<td>1.68</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>2.32</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>1.36</td>
<td></td>
</tr>
</tbody>
</table>

BLACK BAND. A variety of the carbonates of iron, to which attention was first called by Mr. Muxet, at the commencement of the present century. The iron manufacture of Scotland owes its present important position to the discovery of the value of the black band iron stone. This ore of iron is also found in several parts of the coal basin of South Wales, and in the north of Ireland. See Iron.

Chemical examination of the black band, from the neighborhood of Airdrie, about ten miles east of Glasgow, gives the following composition:—

<table>
<thead>
<tr>
<th>Component</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonic acid</td>
<td>35.17</td>
</tr>
<tr>
<td>Proteoxide of iron</td>
<td>53.08</td>
</tr>
<tr>
<td>Lime</td>
<td>3.33</td>
</tr>
<tr>
<td>Magnesia</td>
<td>1.77</td>
</tr>
<tr>
<td>Silica</td>
<td>1.40</td>
</tr>
<tr>
<td>Alumina</td>
<td>0.63</td>
</tr>
<tr>
<td>Peroxide of iron</td>
<td>0.25</td>
</tr>
<tr>
<td>Bituminous matter</td>
<td>3.03</td>
</tr>
<tr>
<td>Water and loss</td>
<td>1.41</td>
</tr>
</tbody>
</table>

BLACK FLUX. An intimate mixture of charcoal and carbonate of potash, obtained by calcining bilastrate of potash. Generally, the crude tartar of commerce is used for this purpose.
BLACING FOR SHOES. According to the "Scientific American," a good paste blacking is made of 4 lbs. of ivory black, 5 lbs. of molasses, 2 oz. of hot sperm oil, 1 oz. of gum arabic, and 12 oz. of vinegar, mixed together, and stirred frequently for six days; it is then fit for use.

Blacking consists of a black coloring matter, generally bone black, and substances that require a gloss by friction, such as sugar and oil. The usual method is to mix the bone black with spern oil; sugar, or molasses, with a little vinegar, is then well stirred in, and strong sulphuric acid is added gradually. The acid produces sulphate of lime and acid phosphate of lime, which is soluble: a tenacious paste is formed by these ingredients, which can be smoothly spread; the oil serving to render the leather pliable. This forms a liquid blacking. Paste blacking contains less vinegar. In Germany, according to Liebig, blacking is made by mixing bone black with half its weight of molasses, and one-eighth of its weight of hydrochloric acid, and one-fourth of its weight of strong sulphuric acid, mixing with water, to form an unctuous paste.—Report of the Progress of Science and Mechanism, New York.

BLAST HOLES. A mining term. The holes through which the water enters the bottom of a pump in the mines.

BLEACHING (Blanchement, Fr.; Bleichen, Germ.) is the process by which the textile filaments, cotton, flax, hemp, wool, silk, and the cloth made of them, as well as various vegetable and animal substances, are deprived of their natural color, and rendered nearly or altogether white. The term bleaching comes from the French verb blanchir, to whiten. The word blanch, which has the same origin, is applied to the whitening of living plants by causing them to grow in the dark, as when the stems of celery are covered over with mould.

The true theory of bleaching has not been entirely agreed upon, but there can be little doubt of the principal operations. It is known that oxygen deprives substances of color; this may be performed by many high oxides; by nitric acid, manganic and chromic acids, chlorous acid, and even lower oxides which hold their oxygen lightly, as hypochlorous acid. The same effect may be produced by chlorine, bromine, and iodine. It has been said that chlorine unites with the hydrogen of the water which is present, gives off oxygen, and so acts just as oxygen would. Davy found that it would not act in dry air, so that water was needful: but Dr. Wilson found that it would act, although slowly, in dry air, if exposed to the rays of the sun. This might show that water is not necessary in order to supply oxygen, but only to allow the chlorine to be brought into thorough contact with the coloring matter. It has also been supposed that the chlorine removes the hydrogen, or, rather, simply takes its place by an act of substitution. Now, whether the chlorine or the liberated oxygen removes the hydrogen, the result will be the same—the destruction of the compound. Chlorine so readily performs these changes, that we should at once decide on calling it the active agent, were it not for the fact that oxygen acts so readily, even when chlorine is not present: for example, peroxide of hydrogen, as well as the oxides just mentioned, and ozone also, which has no chlorine to help it. It is, then, certain that oxidation bleaches; and it is certain that dehydoration bleaches, if performed by chlorine, and that the sun aids it by its active rays. We know also that water aids it: water aids bleaching or oxidation by air, partly because it contains air in solution. It aids also the bleaching performed by solutions in contact with porous bodies, because these bodies have a power of condensing gases in their pores and of compelling combinations. The next question is, Does it aid the bleaching by chlorine in the same way, by assisting the union mechanically, or by decomposing water? Chlorine acts slowly, unless water be present. The theory, therefore, does not demand the decomposition of water, and the known powerful affinities of chlorine do not require to be supplemented by oxygen. But, in order to see exactly the case, let us look at the action of chlorine in hypochlorites or in chloride of lime, and we find that it is a direct oxidation. We obtain by it peroxides of metals, and not chlorides. Here we seem to be taught directly by experiment, that bleaching by hypochlorites is an oxidation of the coloring matter. Bleaching by moist chlorine may therefore be looked on as the same; indeed, we oxidize by it; but in such cases we may obtain the base at the same time united to chlorine, giving another turn to the question, as Kane showed. The oxidation theory, therefore, seems to be sufficient when water is present. We are, however, finally to deal with dry chlorine in the sun; and in that case it is fair to conclude that it acts by direct combination with hydrogen or the coloring matter, or both. We have, then, two modes of bleaching; but the usual mode in the air becomes by that explanation an oxidation, and the direct action of chlorine obtainable only with difficulty. When sulphuric acid is used, another phenomenon may be looked for, as we find a substance whose chief quality is that of deoxidizing. The removal of oxygen also decomposes bodies, and sulphurated hydrogen can scarcely be supposed to act in any other way. Sulphuric acid, when it decomposes sulphurated hydrogen, really acts as an oxidizing agent, and we can therefore imagine it as such in the bleaching process. Investigation has not told us if it enters into combination as SO^4, and, like oxygen, destroys color, altering the compound by inserting itself.
BLEACHING.

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The alkaline solution in which the goods are boiled does not contain above 250 lbs. of carbonate of soda to 600 gallons, but nearly always less. Lime is, however, used much more frequently than soda, which it will be seen is only employed in the second process, and the third, if there be one. It is less hurtful to the cloth, and is much cheaper than the alkalies.

The chloride of lime is used at 3 Twaddle, or 1092⁄5. It is not considered so important now as formerly, and where 300 lbs. were formerly employed, 30 to 40 are now used.

The goods are made nearly white by the alkalies. The chlorine gives only the last finish, and is sometimes used to whiten the ground on colored goods. The whole process may be expressed thus:—Wash out the soluble matter; boil with lime to dissolve still more, and to make a fatty compound with the oily matter; wash out the lime by acids; wash out the fat with a soda soap; clear the white by chloride of lime.

The impurities in the cloth have a certain power of retaining color upon them. Mud and dirt, as well as grease, gluten, and albuminous matters, have this property, and fatty soaps, such as lime compounds of fatty acids. The pure fibre, however, has no power of taking up solutions of such coloring matter as madder. When, therefore, it is desired to try the extent to which cloth has been bleached, it is dyed or boiled up with madder exactly as in the process of dyeing. It is then treated with soap, as the madder-dyed goods are treated, and if it comes out without a stain, or nearly pure white, the goods are ready.

Dyers or calico-printers who dye printed goods are exceedingly particular as to the bleaching, the dyeing and printing having now approached to such exactness, that shades invisible to any eye not very much experienced are sufficient to diminish in a material degree the value of the cloth. Any inequality from irregularity of bleaching, which causes a similar irregularity of dyeing, is destructive to the character of the goods. Many patterns, too, have white grounds; these grounds it is the pride of a printer to have as white as snow. If delicate colors are to be printed, they will be deteriorated if the ground on which they are to be printed is not perfectly white.

Old Methods still in use.—As a specimen of the older processes, we shall give the following, adding afterwards a minute account of some of the plans adopted by the most successful bleachers. When grease stains do not exist, as happens with the better kind of muslins, or when goods were not required to be finely finished, the following has been adopted:—After singeing, 1. Bolling in water. 2. Scouring by the stocks or dash-wheel. 3. Bucking with lime. 4. The bleaching property so called, viz., passing through chlorine or chloroform. 5. Bucking or bowking with milk of lime. These two latter processes employed alternately several times, till the whole of the coloring matter is removed. 6. Scouring. 7. Washing.

The Processes used in Bleaching. Singing.—The singeing is performed by passing the cloth over a red-hot plate of iron or copper. The figure 30 shows this apparatus as improved by Mr. Thom. At a there is a cylinder, with the cloth wound round it to be singed; it passes over the red-hot plate at b, becomes singed, passes over a small roller at c, which is partly immersed in water, and by this means has all the sparks extinguished; then is wound on to the roller d, when the process is finished. As the products of combustion from the singeing are sometimes very unpleasant, they are carried by this apparatus into the fire-place, where they are consumed. The arrows show the passage of these vapors from the surface of the cloth downwards into the hearth, and thence into the fire.

For goods to be finely printed both sides are singed; for market bleaching, one side. Sometimes, however, singeing is not at all desired.

The use of a flue of gas jets instead of a red-hot plate, was introduced by Mr. Samuel Hall. It has not, however, found its way generally into bleach works: the plate is preferred. Gas jets are used necessarily in singeing threads.

Shearing.—For fine printing, it is by some considered needful to shear the nap of the cloth instead of singeing it. The method is more expensive than singeing. Messrs. Mather and Platt have made a machine which will shear 60 to 80 yards per minute.

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Bleaching or Bowking.—This is the process of boiling goods. It is performed in alkaline liquids, generally lime or soda, or both. The kier for bowking is a cylindrical iron vessel, constructed so as to render the boiling free, and prevent the goods from being burnt on the bottom. The kier of Messrs. Mather and Platt is very complete. The first figure (51) is the kier when shut or screwed down. The second figure (52) is the section of the kier, which is very like that before given; but in this case it is steam-tight, and heated by steam which issues from a steam pipe communicating beneath the false bottom. The dangers attending the kier before mentioned are by this means entirely averted, and all the inventions which give the washing liquid a separate and distinct place for heating are at once done away with.

An exact description of these kiers is required. a, b, c, d, represent the body of the kier, which is a cylindrical vessel, generally made of cast-iron, but sometimes of wood, or wrought iron. h, represents false bottom—a cast-iron grating sometimes covered with boulder-stones, and sometimes with wood; g, cylindrical disk, of wrought iron, placed on the top of "," puffer-pipe, to spread the liquor over the cloth. q, " puffer-pipe," standing on false bottom, k, x, cylindrical casing for supporting false bottom and " puffer-pipe," whose periphery is " slotted," to admit of the liquor passing through. n, cover for kier; the flanch on which this cover rests is grooved a little, to admit of " gasking " being inserted, so as to form a " joint." k, k, swivel bolts, holding down the cover. i, a small aperture, covered with a lid capable of being removed easily, to enable the attendant to see that the cloth does not rise too high in the kier to endanger its working; if such happens, he checks the steam until the cloth settles, after which it does not again attempt to rise. n, steam valve; l, water valve; both communicate with pipe w, leading to kier. r, pipe communicating with kier for supplying steam and water—also serves as escape pipe; f, escape valve for letting off kier; c, wheel for opening ditto; m, steam pipe from boiler. o, p, foundation for kier.

The process of cleaning is very various. Some use lime for the first process; some use soda alone; and some use them mixed. Of course, when carbonate of soda and lime are used, caustic soda is at once formed, and the carbonate of lime is left idle. The practices and fancies of bleachers are numerous; and we have only to say that the principle consists in the use of alkaline lyes. Some use lime to the amount of 3 per cent.; others go as high as 10. The lime is slaked first and a portion thrown in; a portion of cloth is laid upon it, and a portion of lime again covers that; but on no account must the goods be allowed to lie in contact with the atmosphere and the lime.

When removed from the kier the goods must be washed. Now, if they are to be washed in dash-wheels, it is needful that they be in separate pieces, and in this state they are sometimes boiled in the kiers; but if they are to be washed in the washing machines, they are lifted out of the kier in the same manner as a piece of string is drawn out of the canister in which the coil is kept.

M. Metz, of Heidelberg, has attempted to perform the work of boiling by merely extracting the air from the cloth. For this purpose the cloth is simply put into a strong upright cylinder, the top screwed down, and the air taken out by an air-pump. We have no knowledge as to the advantages gained by this process, or whether it has been found actually capable of putting cloth in a condition to be bleached for a very fastidious market.
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Steeping.—Instead of boiling in the kier at first, the goods are sometimes, though now rarely, steeped from one to two days in water, from 100° to 150° F., for the purpose of loosening the gummy, glutinous, and pasty materials attached to the cloth. Fermentation ensues, and this process is dangerous, as the action of the ferment sometimes extends to the goods, especially if they are piled up in a great heap without being previously washed. The spots of grease on the insoluble soaps become thereby capable of resisting the caustic alkalis, and are rendered in some measure indelible: an effect due, it is believed, to the acetic and carbonic acids generated during fermentation. Some persons throw spent lies into the fermenting vats to counteract the acids. The spots of grease are chiefly to be found in hand-loom goods, and the difficulty concerning the fats is not therefore commonly felt where power-loom goods are chiefly used, as in Lancashire.

Washing.—The machine made by Mr. Mather (figs. 53 and 54) washes 800 pieces per hour, or 8,000 pieces per day of 10 hours, using 400 gallons per minute, or 120,000 gallons per day, or 20 gallons to a piece. This class of machine is now in its turn superseding the dash-wheel.

This washing machine will be understood by the general plan, (fig. 54, and corresponding section, fig. 53.) a and b represent the squeezing-bowls. a is 18 inches diameter and 8 feet 3 inches long; it is made of deal-timber. (The lapping of strong canvas at a is for the purpose of giving the "out-coming" pieces an extra squeeze, in order to prepare them for the kiers.) b is 24 inches diameter and of the same length as a, making 100 revolutions per minute; it is generally made of deal, sycamore, however, being better. c, d, a strong wooden rail, in which pegs are placed in order to guide the cloth in its spiral form from the edge to the centre of the machine. k, h, the water-trough, through which the piece passes round the roller. p, (fig. 53,) water-pipe; r, water-tap; m, m, pot-eyes, which may be adjusted to any angle, to guide and regulate the tension of the piece on entering the machine. l, side frame, for carrying bowls, &c.; g, engine (with cylinder, 8 inches diameter) and gearing for driving machine; w, weight and lever for regulating pressure on the bowl.

This machine washes 800 pieces per hour, and requires 400 gallons of water per minute. It will serve also to represent the chemick and souring machine, the only difference being that the bowls are 3 feet 6 inches, instead of 8 feet 3 inches, in length.

The chemick and sour are brought by turns into the trough, or into similar separate troughs, by a leaden pipe from the mixing cisterns, and are run in to 6 or 8 inches deep.

The washing machine of Mr. Bridson (fig. 53) is worth attention. In its action the course of the cloth in the water is easily seen; it is chiefly horizontal. This motion had been given by Hellewell and Fearn in 1836; but they had a very complicated machine, and they did not attain the flapping motion which is given to the cloth when it becomes suddenly loose, and is driven violently against the board a a as often as b c and e d are in one line. It is not shown by the drawing that the cloth passes eight times round these wheels. There is a constant stream of water from the pipe f, which is flattened at the mouth about one and a half inches in one diameter, and about ten inches in the other. This machine can wash 900 pieces in an hour. It requires about twice as much water as a dash-wheel, but washes seven and a half times more pieces. Its length is nine feet.
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Souring.—After boiling in the first kier and washing, the goods are sourcd in muriatic acid of 1010° specific gravity, or 64 gallons of the usual acid, which contains 53 per cent. of real acid, mixed with 100 gallons of water. This is equal to 2° Tw. Muriatic acid may be replaced by sulphuric acid of 1024° specific gravity, i.e., 52 gallons liquid acid to 100 of water; or the amount of the acid may be doubled in either case, and a shorter time allowed for the souring. The souring is performed in wooden or stone cisterns, where the cloth is laid regularly as it falls over one of the rollers of the calender;—or it is passed through the acid solution by the movement of the calender in the same manner as described in the process of washing. If this method is used, it is allowed to lie on the stillages from two to three hours to allow the acid to act. The acid decomposes any lime soap formed, and washes out the lime. Hydrochloric or muriatic acid has been preferred in the process described, as the chloride of calcium is so much more soluble than the sulphate. After souring, of course the goods must be thoroughly washed as before.

The sixth operation with soda removes the remaining fatty materials. If lime be used, it may be allowed to settle; and it is better to allow it to do so, and thus to use pure caustic soda, which will with the resin remove the impurities in a more soluble form. If, instead of adding 170 lbs. of soda crystals to 600 gallons of water, 4½ lbs. of liquid caustic soda of specific gravity 1320° were added, the effect would be the same.

The solution of resin and carbonate of soda is a half-formed soap, which is considered to act beneficially in moving the soluble matter. It would not appear, from theory, to be capable of doing so well as the soda which has its carbonate acid removed; but tender goods will not allow the action of caustic soda, and the carbonate is therefore safer.

Powder-bleaching.—Chloride of lime is added in stone vessels where the goods are allowed to lie. It is universally called chemick in the manufactories. The strength used at Brickacre is half a degree Twaddle, or 1002:5. This is sometimes very much increased, so as to be even 5° in some establishments, according to the goods bleached; but it is not safe to allow the cloth to lie long in such strong solutions. In such cases it is needful to pass them rapidly through with the calender, so as to soak them thoroughly, and then to pass them on to the acid, and forward to be washed. It may be remarked that the use of the calender for these operations renders it possible to use strong solutions, even for tender goods, as there is no time given for injurious action on the fibre.

Great care is to be taken to make the solution of the chloride of lime perfectly clear. The powder does not readily wet with water, and it must therefore be pressed or agitated. It may be well to agitate it in a revolving barrel, or to suspend it in a revolting barrel of water, until complete saturation of the powder with moisture; the amount required is then thrown into the cisterns, and the insoluble matter allowed to sink. This insoluble matter must not be allowed to come into contact with the cloth, as it will be equal of course to a concentrated solution of the liquor, and will produce rottenness, or burn the cloth so as to leave holes. When removing from the trough, the cloth is drawn through squeezing rollers, which press out any excess of chloride of lime.

Squeezing.—A squeezing machine, with a small engine attached, is shown in fig. 55, for the drawing of which we are again indebted to the makers, Messrs. Mather and Platt.

$\delta, \phi$ represent the squeezing bowls. They are as large in diameter as possible, and are generally made of sycamore; but the bottom one is better made of highly compressed cotton. $\alpha, \beta$ are the engine and frame for driving; $\gamma$ frame for carrying bowls; $\iota, \iota$ compound levers for regulating the press use; $\sigma$ is a screw for the same purpose, and $\epsilon$ the cloth passing through the bowls.

The white-squeezers, or those used before drying, should have a box, supplied with hot water, fixed so that the piece may pass through it before going to the nip of the bowl.

When the goods are run through, they are carried off upon a grated wheelbarrow in a nearly dry state, and transferred to the spreading machine called at Manchester a rendrope. In many bleach-works, however, the creased pieces are pulled straight by the hands of women, and are then strongly beat against a wooden stock to smooth out the edges. This being done, a number of pieces are stitched endwise together, preparatory to being mangled.

This squeezing machine is small, but, as will be seen, the rollers are introduced so as to act as long and as rapidly as cloth of whatever length is drawn through them.

The following figure (97) represents a pair of squeezers, for squeezing the cloth after several of the processes named, and are shown as being driven by a small high-pressure engine. $a$ is the fly-wheel of engine; $b$, crank of ditto; $c$, frame of engine; $d$, spur-wheels connecting the engine and squeezers; $e$ and $f$, sycamore squeezing bowls.

The cloth when passed over the steel rollers is now dry; but it is not smooth and ready for the market. If the cloth is wanted for printing, no further operation is needed; but if to be sold as white calico, it is finished by being starched and calendered.

The starch at large works is prepared by the bleachers themselves. At Messrs. Bridson's it is made with the very greatest care from flour. Of course it would be more expensive for them to buy it, as the manufacturer would dry it, and they would require to dissolve it. They are able also, in this manner, to obtain the purest starch. This is mixed with blue,
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according to the finish of the goods. A roller, which dips into the starch, lay it regularly and evenly on the cloth in the same manner as mordants are communicated in calico-printing, whilst other rollers expel the excess of the starch. The cloth is then dried over warm cylinders, or by passing into a heated apartment. It receives the final finish generally by the calender; but muslins receive a peculiar treatment. See Calender, vol. i.

Finishing.—Pure starch is not always used for the purpose of finishing. Fine clay, gypsum, or Spanish white, is mixed with the cloth; and if weight is desired to be given, sulphate of baryta is employed. Mr. John Leigh, of Manchester, has lately patented for this purpose the use of silicate of soda, which, for such goods as are not injured by alkalies, seems to answer the purpose at a very cheap rate. There can, however, be no doubt that too much attention is given to this finish for home goods, or for all purposes which require the goods to be washed; they assume a solidity of appearance which they do not possess when the finishing material is removed from the pores, and the cloth appears without disguise. In some instances, however, this finish is a peculiarity of the goods, and is almost as important as the cloth itself. For example: in the case of muslins, when they are dried at perfect rest, they have a rigid inelastic feeling, somewhat allied to that of thin laths of wood, and feel very rough to the touch. They are therefore dried by stretching the cloth, and moving the lines of selavage backward and forward, so as to cause the threads of weft to rub against each other, and so as to prevent them becoming united as one piece. Goods dried in this manner have a peculiar spring, and such thick muslins are for a time possessed of great elasticity. Several pieces folded up in a parcel spring up from pressure like caoutchouc.

Mr. Ridgeway Bridson invented an apparatus for giving this peculiar finish to muslins. Formerly it was done entirely by the hand, and in Scotland only. Since the invention of this machine, this trade has become a very important one in the Manchester district.

Sometimes goods are finished by the beetle, which acts by repeated hammering. This peculiar action has been transferred to a roller by T. R. Bridson, and called the "Rotatory Beetle." It consists of a cylinder having alternately raised and depressed surfaces, and two other cylinders which press upon it, and alternately press the cloth and give a freedom as it passes between the rollers. This is similar to the rise and fall of the hammers or mallets in the beating process.

Sometimes a stiff finish is wanted; then muslins are dried in the usual way.

Drying.—Figs. 58 and 59 represent a drying machine, with eleven cylinders, each 22 inches in diameter, capable of drying 1,000 pieces of bleached calico in a day. A represents cylinders heated with steam; 6, vacuum-valves in ditto; 7, frame for carrying cylinders; 8, folding apparatus; 9, steam-pipe; 10, gearing.

When goods are dried having a raised pattern, such as brocades, or any other, such as striped white shirting, only one side of the cloth is to be exposed; the pattern rises up from the heated surface on which the cloth is dried. For this reason, cylinders such as those just described cannot be used. Large wheels of cast-iron are employed, consisting of two concentric cylinders, between which is a closed space heated by steam. The cloth is by this means heated on one side only, not passing from cylinder to cylinder, in which case the side next to the heating surface would be changed every time. The larger the cylinder or wheel, the more rapid is the drying, as there is more surface of cloth exposed to it at a time; it can, for the same reason, be turned more rapidly round. Well-finished goods will not rise when heated, except on the pattern. Messrs. Bridson have a large business in jacquards for artificial flowers on account of this peculiar finish. They are formed of a plain cotton cloth, but stand the pressure of hot irons without curling.
No essential difference is made in bleaching muslins, except that sometimes weaker solutions are employed for very tender goods. Mr. Barlow makes no difference as a rule in the strength given in describing his process; with very strong goods, he sometimes uses the liquids stronger. It is desired occasionally to bleach goods which have colored threads woven into them, or colors printed on them. In these cases great caution must be used. It is needful to use weak solutions, but more especially not to allow any one process to be commenced very long, but rather to repeat it often than to lengthen it. This may be stated as a general rule in the bleaching of goods. It would indeed be possible to do the whole bleaching in one operation, but the cloth would be rotten. This arises from the fact that, at a certain strength, bleaching liquid or soda is able to destroy the fibre; but another and less strength does not act on the fibre, but only on such substances as coloring matters. This care is needed when printed goods which have a white ground are treated. The white ground takes up color enough to destroy its brilliancy, and soaping does not always remove it. The bleaching then is effected by using bleaching liquor at 3 Twad. Some persons put a Turkey red thread into the ends of the pieces. The original use of this seems to be scarcely known among the manufacturers. It was used as a test of the mode of bleaching employed. If strong solutions be used, which are apt to spoil the cloth, the color of the dyed threads will be discharged. When the separate system is employed, this is evaded easily; it is the practice to keep the ends containing the red threads out of the liquid, allowing them to rest on the side of the vessel.

Sometimes chlorate of potash is used for the same purpose, souring as with the bleaching powder. The colors may, in this manner, be made much more brilliant than before, although a little excess will discharge them." A good deal of the effect may be owing to the better white given to the ground. Besides these processes for bleaching, another was at one time introduced, which consisted of immersing the cloth in a solution of candle alkali, and afterwards steaming in a close vessel. It is not now in use. Alkali of 1020° specific gravity was used.

The new or continuous Process.—This method owes its introduction to David Bentley, of Pendleton, who patented it in 1828. It consists in drawing the goods in one continuous line through every solution with which it is desired to saturate them. This is done by connecting the ends of all the pieces. The motion of rollers draws the chain of cloth thus formed in any desired direction, and through any number of solutions any given number of times. We shall allow him to use his own words:

Fig. 60 is an end view of two such calenders, each having two larger rollers a and b, a smaller driving roller c, two racks d and e, 1, placed upon two cisterns g and h, 1, inside of which cisterns are two rollers n and p, 1, which rollers have four square ribs upon each, to shake the goods as they pass through the cisterns. At r is a frame upon which the batches of goods are placed upon rollers shown in Fig. 61, where they are marked k, k, k, k. The calender checks are made fast at the feet, at the middle, and to the top of the building, having levers and weights h to give pressure to the calender bowls.

Near the end walls of the building are two rollers, one of which is shown at a; upon each of these is a soft cord used as a guide for conducting the goods through the machinery and cisterns. The operation is commenced by passing one end of the cord through the rollers a and c, down to cistern g, under roller e, through the furthermost division of rack d, and again through calender rollers at b and c, repeating the same, but observing to keep
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The idbxi'jB under 2, 9, this every rh 4, and lime the the in only. The guide roller 3, through the nearest division of rack d 1 into cistern g 1, under roller e 1, over guide roller 2, and again over roller c, under and round n 1. This course must be repeated, observing as before to keep the cord tight, and to receive one division of rack d 1 every revolution, until each division of rack d 1 is occupied, when the end must pass over n 1 under 14. The cord now forms a sort of spiral worm round and through the machinery and cisterns, beginning at b, c, and ending at the top of n 1 to 14, the number of revolutions being governed by the number of divisions in the racks d and d 1, so that if there were fifteen divisions in each rack, there would be fifteen revolutions under c, round n through d, under d and b, and fifteen revolutions over c round n 1, over d 1 through d 1 and c 1, under n 1 over 12, and again over c, passing from the top of b 1 to 14; and by this means, if one end of the back of goods marked k, and placed upon the frame v, (fig. 61.) is fastened to the end of the guide cord, the goods will, when the calender is put in motion, be conducted and washed thirty times through the water in the cisterns, and squeezed thirty times through the calenders. As the operation proceeds and the guide cord passes through the calender, it is wound by hand upon roller l to prevent it from becoming entangled, and to keep it in readiness for the next operation. As soon as the first end of the goods has passed through fig. 61, and arrives at the guide roller 14, it is detached from the end of the guide cord and attached to the guide cord to the other end, or with the opposite set of calenders. After this, by putting these in motion, the goods are washed and squeezed through its cisterns, which cisterns are supplied with hot and strong lime lye, and the goods passing over guide roller 15, they are conveyed over other guide rollers to be placed for the purpose, and taken down by some person or some proper machinery into one of the boiling vessels, where, steam or fire heat being added, they are suffered to remain while the lime-boiling takes effect.

We need not follow the inventor into all the particulars. When the goods were sufficiently acted on by one solution, another solution was used, so that this mode of calendering not only was a method of moving the goods from place to place by means of rollers, but it was a method also of saturating goods thoroughly with a solution, and of washing them.

It was by a similar method that Mr. Bentley bleached skeins of yarn, of linen, or of cotton. The skeins are looped together by tying any soft material round the middle of the first skein, which will leave the loops from one end of the next skein to pass half-way through, and which will always leave other two loops, and by repeating which any quantity of skeins may be looped together, tying the last loop with another soft material.

The mode of saturating the goods with solutions is effected by the arrangement shown in fig. 62. Rapid motion and frequent pressure are introduced instead of a still soaking process.
A is a roller for the guide cords; B, B, B, are eleven washing rollers; C, C, C, are speed rollers; D, D, D, are twelve rollers immersed in twelve divisions of the cistern E. The eleven staple-formed irons which pass through the frame rails on each side of the centres of the eleven rollers B, B, B, and the eleven rollers C, C, C, serve to stay these rollers in their places, at the same time allowing the eleven washing rollers D, D, D, to rise and fall according to the pressure by which they are held down, by the eleven weights attached to these irons at H, and upon the bottom rail may be placed such staves, brushes, or rollers, as may be found necessary for holding and brushing the goods in the best manner to keep them straight during the different washings in water and bleaching liquors. The goods are prepared by steeping, as before described, and placed in batches at F, and passing under the immersing rollers E and the twelve divisions of cistern E, between the eleven speed rollers C and the eleven washing rollers D, as seen at K, are taken down straight and open into one of the vessels, and are then boiled by steam, which is succeeded by repeated washings alternately in water and bleaching liquors, until they are sufficiently bleached, as before described.

The elevation and ground plan of a bleach-house and machinery capable of bleaching 800 pieces of 4 lbs. cloth per day, (for best madder work,) with the labor of one man and three boys, working from 6 until 4 o'clock, exclusive of singeing and drying, are represented in figs. 63 and 64, (p. 156.) The letter D represents two lengths of cloth of 400 pieces each, (end of pieces being stitched together by patent sewing machine made by Mather and Platt,) making together 800 pieces, passing through washing machine G, and from thence delivered over winch, W, into kier, C,—this operation occupies one hour,—where they are boiled for twelve hours in lime. They are then withdrawn by the same washing machine, G, washed, and passed into second kier, H, (operation occupying one hour,) where they are boiled for twelve hours in ashes and resin; again withdrawn by the same machine, G, washed, squeezed, (see plan at W,) and passed over winch, C, and piled at H, (this operation occupies one hour.) They are then taken from pile, H, and threaded through sour-machine, S, soured, passed over winch, E, and piled at K, (operation, one hour,) where it remains in the pile for three hours. It is then squeezed at V, and washed through machine, G, (an hour's operation,) delivered into third kier, A, boiled for six hours, washed at G, squeezed at V, (an hour's operation,) and passed through chemick machine, (an hour's operation,) and piled for one hour; after which it is soured again, (an hour's operation,) squeezed, and washed at G, (an hour's operation,) squeezed again at F, (an hour's operation,) and dried by machine at P, (fig. 63.)

There are several advantages in using the squeezing process so often in the above arrangement:—Firstly, The bowls of the washing machine are not so much damaged by the heavy pressure which is required to be applied, if no squeezers are used, in order to prepare the pieces for the sour and chemick machines: Secondly, A drier state of the cloth than can possibly be produced by the washing machine alone, thus fitting it to become better saturated with the chemick or sour: Thirdly, The piece passing from the souring to the washing machine, in this arrangement, carries with it less of the acid, and thus ensures a better washing with less water.

It may be observed, that the velocity of the above-mentioned machines is much higher than usual, experience having shown that the various operations are thus better performed.
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than when running slower. The reason of this appears to be, firstly, that the piece, running at such velocity, carries with it, by reason of capillary attraction, a greater quantity of liquid to the nip of the bowls; secondly, the great velocity of the bowls, together with the greater quantity of water carried up, produces a more powerful current at the nip and down the ascending piece, thus penetrating to every fibre of it. It may also be remarked, that the above-mentioned machines are not adapted to the bleaching of linen; for the latter cloth, not having the same elasticity as cotton, if it should become light, would either be pulled narrow or torn.

In illustration of the continuous process as at present used, the plan of proceeding at Messrs. McNaughten, Barton, and Thom's, at Chorley, may be described:

1. In order that there may be no interruption in the process, the pieces are united in one continuous piece—each piece being about 30 yards, the whole varying with the weight of cloth—about 300 yards long. Each piece is marked with the name of the printer. This is sometimes done in marking ink of sliver, and sometimes in coal tar, at the extremity of the piece. The pieces are rapidly tacked together by girls, who use in some establishments a very simple sewing machine. (See Sewing Machine.) The whole amount to be bleached at a time is united in one piece, and is drawn from place to place like a rope. To give them this rope form, the goods are drawn through an aperture whose surface is exceedingly smooth, being generally of glass or earthenware. Of these many are used in transferring the cloth from place to place. They serve instead of pulleys. The cloth when laid in a vessel is not thrown in at random, but laid down in a carefully made coil. The rope form enables the water to penetrate it more easily.

2. The pieces are singed.

3. They are boiled in the first kier. In this, 3,500 lbs. of cloth have added to them 250 lbs. of caustic lime, 1 lb. of lime to 14 of cloth. The kier is cylindrical, 7 feet deep and 8 feet in diameter; as much water is added as will cover the cloth, about 500 gallons. This boiling lasts thirteen hours.

4. They are washed in the washing machine. Robinson and Young's machine is used.

5. They are soured in a similar machine with hydrochloric acid of specific gravity 1010; or 3/4 of Twaddle.

6. The same amount of cloth being supposed to be used, it is bucked in a solution of soda-ash and resin, 170 lbs. of soda-ash to 30 lbs. of resin. The boiling lasts sixteen hours, the same amount of water being used.

7. Washed as before.

8. Passed through chloride of lime, or chemicled. The cloth is laid in a stone or wooden cistern, and a solution of bleaching powder is passed through it, by being poured over it and allowed to run into a vessel below; this is managed by continued pumping. This solution is about half a degree Twaddle, or specific gravity 1002/5. The cloth lies in it from one to two hours.


10. Boiled again in a kier for five hours with 100 lbs. of carbonate of soda crystals.


12. Put in chloride of lime as before.

13. Soured, in hydrochloric acid of 1012-5 specific gravity, or 2 1/2 Twaddle.

14. Lies six hours on stillages.—A stillage is a kind of low stool used to protect the cloth from the floor.

15. Washed till clean.


17. Dried over tin cylinders heated by steam.

This is the process for calico generally; some light goods must be more carefully handled. The usual time occupied by all these processes is five days. They are sometimes dried in a hydro-extractor; after singeing, laid twenty-four hours to steep, then washed before being put into the lime kier.

High-pressure Steam Kier.—This is designed still further to hasten the process of bleaching, and at the same time to improve it.

Fig. 65 is an elevation showing the arrangement of these kiers, (which are recommended to be made of strong boiler-plate iron.) One of these is shown in section. a and b are the kiers; c is a perforated platform, on which the goods to be bowked are laid; k is the pipe connecting the bottom of the kier b with the top of the adjoining kier, a; and k, k, the corresponding pipe connecting the opposite ends of the kiers a and b; m m are draw-off cocks, connected with the pipes k and k, by which the kiers can be emptied of spent liquor, water, &c.; n and o are ordinary two-way taps, by which the steam is admitted into the respective kiers from the main pipe, p, and the reversing of which shuts off the steam communication, and admits the bowking liquor as it becomes expelled from the adjoining kier; q is a blowing-off valve or tap; r, the pipe through which the bowking liquor enters into the kier; s, manhole, (closed by two cross bars, secured by bolts and nuts,) through which
the goods are introduced and removed; *t t* are gauges, by which it is ascertained when the liquor has passed from one kier and has entered the other.

The process adopted for bleaching is as follows; it is the shortest and simplest in use:

1. The box or water trough of the washing machine is then half filled with milk of lime of considerable consistence, and the goods are run through it, being carried forward by the winches and passed in the kiers. The whole of the cloth in a kier is in one length, and a boy enters the vessel to lay it in regular folds until the kier is filled. All the cloth before entering the kier must pass through the lime.

2. When the kiers are filled, a grid of movable bars is laid on the top of the cloth, and the manhole of the kier is closed. High-pressure steam is then admitted at the top; this presses down the goods and removes the lime water, which is drawn off at the bottom. At the same time the air is also removed from the goods and replaced by steam. When this is driven off, and nothing but steam issues from the tap at the bottom, 40 lbs. of lime, which have been previously mixed with 600 gallons of water, are introduced into the first kier in a boiling state. High-pressure steam is again admitted, which forces the lime liquor through the goods to the bottom of the vessel, then up the tube *f*, and on to the goods in the second kier. The tap is then closed which admits steam into the first kier, and the steam is now sent into the second. The same process occurs, only in this case the liquid is sent again on to the top of the goods in the first kier. This process is continued about eight hours.

In this method each 7,000 lbs. of cloth take into the kiers 2 cwt. of lime, which is equally distributed. The clear lime-water which is blown out of the steam at the commencement contains only 3 to 4 lbs. of lime in solution. At the close of the operation the liquor has a specific gravity of 2 to 4° Twaddle, (1017-5 to 1020), instead of half that amount, or 1° to 2° Twaddle, (1007-5 to 1010), as is usual.

3. When the lining is completed the steam pressure in the kiers is removed, the manway opened, the grid lying above the cloth removed, and the cloth in the kier attached to the washing machine, which draws the goods out of the kiers and washes them.

4. The pieces are then passed by the winches through the souring machine, or soured
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by having muriatic acid of 2° Twaddle pumped upon them, (1010.) They must remain with the acid two or three hours, either steeped in it, or after having passed through it.

5. Again attach the cloth to the washing machine, and wash it well, passing it on by winches, as before, into the kier.

6. Introduce steam and drive off the air and the cold water; these are let out by the tap at the bottom: add then 224 lbs. of soda-ash and 150 lbs. of resin, boiled in 600 gallons of water, for 7,000 lbs. of cloth. Work the kiers by driving the liquid from one to the other as before; about eight hours is a sufficient time. These proportions of soda may be varied. If the cloth is very strong, a little more may be used, (or if the cloth has been printed upon in the gray state, from having been used to cover the blanket of the calico-printing machine.)

7. After this the cloth is passed through the washing machine, and then submitted to chloride of lime. This may be done either by the machine or by pumping. In either case it is an advantage to warm the bleaching liquid up to 80° or 90° F. The strength of the solution when the machine is used may be about 3° Twaddle, or 1002·5 specific gravity; but if the pump is used it must be much weaker. When the bleaching is for finishing white, milk of lime is added to the chloride, in order to retard the operation; the goods are also washed from the bleaching liquor before souring them. This causes a similar escape of chlorine, and is a more careful method; it tends to preserve the headings, or the colored threads, which are often put into the ends of pieces of cloth in order to see if the bleaching has been performed roughly or not. The original use of this has almost been forgotten, but these headings are still carefully preserved. This method preserves also the cloth, which is also less apt to be attacked by the chloride.

If the cloth has been well managed, it will be almost white when it leaves the second kier containing the resinate of soda; it will therefore require very little decolorizing. If the goods have been printed on, more chloride will be needed. The cloth should lie from two to eight hours in the liquor, or after saturation with it. The action is quickened if warmth is used. They are sourd then, as before, in muriatic and sulphuric acid, at 2° Tw., for three or four hours; then wash for drying.

This method of Mr. Barlow's is an undoubted shortening of the process of bleaching; eight hours only of bucking are found to be enough, and the whole may be performed, by the help of the continuous system, in two days. It will be seen that the steam drives the solution through the cloth; and this is equal to the process of stirring, which is a continual change of surface and of liquid, but it is more effectual than any stirring could possibly be. The goods are laid in a firm, compact mass, and held down by an iron grid, so that the liquid cannot run through rats and crevices, but must run through the cloth itself.

From what has been said, it will be seen that the operations of the bleacher are not so numerous as at first sight appears, when we call every washing a separate process; and although it really is so, it is managed so rapidly that it can scarcely be said to occupy time, and as it is carried on at the same time as the other processes, it scarcely can be said to give trouble. The work may be divided into:—

1. Singing.
2. Bowling with lime.
3. Washing, souring, and washing.
4. Bowking with resinate of soda.
5. Washing and chlorinating.

This process has been tried with success on linen, although not yet in active operation.

Bleaching of Linen.

Old Method.—What is called the old method, or that used from about the introduction of bleaching powder, at the beginning of the century, till within ten or fifteen years, required bleaching on the grass; and the mode in which it was managed in Ireland and Scotland, where it held its ground longest, is as follows:—

1. They were rot-steeped in a weak solution of potash, at about 130° F., for two days, until the dressing used in manufacturing the cloth was removed.
2. Washed.
3. Boiled or bowked in potash lye, at 2° Twaddle, for ten hours.
4. Washed, and the ends turned so that the whole might be equally exposed to the lye.
5. Boiled or bowked in a similar lye to the above for twelve hours.
6. Washed well.
7. Exposed on the grass for three days, and watered.
8. Taken up and added with sulphuric acid, at 2° Tw., for four hours.
9. Taken up and washed well.
10. Boiled again for eight hours in potash lye, at 1° Tw., to which had been added black or soft soap, about 20 lbs. to a kier of about 300 gallons.
BLEACHING.

12. Crofted, or exposed on the grass, as before.
13. Treated with chloride of lime at 1½ ° Tw., for four hours.
15. Soured in sulphuric acid, at 2° Tw., for four hours.
17. Boiled for six or seven hours with soap and lye, using in this case more soap and one-third less lye than in the former bowkings.
18. Drawn out and put through rub-boards. This is a kind of washing machine, made of blocks of wood, with hard-wood teeth. The goods are washed by it in a soapy liquid. The teeth, moving rapidly, drive the soap into the cloth.
20. Washed.
21. Crofted, keeping them very clean, as this is the last exposure.
22. Treated with chloride of lime.
23. They are then starched, blued, and beetled, to finish them for the market. These operations last six weeks.

New System, as practised in Scotland and Ireland.—Directions given by an extensive Bleacher.

1. Wash.
2. Boil in lime-water ten or twelve hours.
3. Sour in muriatic acid, of 2° Tw., for three, four, or five hours.
4. Wash well.
5. Boil with resin and soda-ash twelve hours.
6. Turn the goods, so that those at the top shall be at the bottom, and boil again as at No. 5.
7. Wash well.
8. Chemick, at ¼ ° Tw., or 1002-5, four hours.
9. Sour, at 2° Tw., or 1010° specific gravity.
10. Wash.
11. Boil in soda-ash ten hours.
12. Chemick again.
13. Wash and dry.

This is the system chiefly adopted when the goods are to be printed.

The following is the system practised in the neighborhood of Perth, where the chief trade is in plain sheetings:—

1. Before putting them into operation, they are put up into parcels of about 35 cwts.
2. They are then steeped in lye for twenty-four hours.
3. Then washed and spread on the grass for about two days.
4. Boiled in lime-water.
5. Turned, and boiled again in lime-water, those at the top being put at the bottom.
6. Washed, then soured in sulphuric acid of 2° Tw., or 1010° sp. gr., for four hours, then washed again.
7. Boiled with soda-ash for ten hours; 110 lbs. used.
8. Washed and spread out on the green, or crofted.
9. Boiled again in soda as before.
10. Crofted for three days.
11. They are then examined: the white ones are taken out; those that are not finished are boiled and crofted again.
12. Next, they are scalded in water containing 80 lbs. of soda-ash, and washed.
13. The chloride of lime is then used at ¼ ° Tw., or 1002-5 specific gravity.
14. Washed and scalded.
15. Washed and treated with chloride of lime.
16. Soured, for four hours, with sulphuric acid, at 2° Tw., or 1010° specific gravity.
17. Washed.

If cloths lighter than sheetings are used, the washing liquids are used weaker. The great point is to observe them carefully during the process, in order to see what treatment will suit them best.

It will be seen that the process of bleaching linen is still very tedious; and although it may be managed in a fortnight, it is seldom that this occurs regularly for a great length of time. The action of the light introduces at once an uncertain element, as this varies so much in our climate. If, again, linen be long exposed to the air in a moist condition, it is apt to become injured in strength. To shorten the process, therefore, is important; and if no injurious agents are introduced, a shortening promises also to give increased strength to the fibre. It has not been found possible to introduce chlorine into linen bleaching at an early stage, as in the case of cotton; and the processes for purifying it without any chlorine render it so white that unskilled persons would call it as white as snow. The chlorine is
introduced nearly at the end of the operation, after a series of boilings with alkalies, sounings, and exposures on the grass. If introduced at an earlier stage, the color of the raw cloth becomes fixed, and cannot be removed. The technical term for this condition is "set." Mr. F. M. Jennings, of Cork, has just patented a method which promises to obviate the difficulty. The peculiarity consists in using the alkali and the chloride of alkali at the same moment, thus giving the alkali opportunity to seize on the coloring matter as soon as the chloride has acted, and thereby preventing the formation of an insoluble compound.

He prefers the chlorides of potash or soda. His plan is as follows:—
1. He soaks the linen in water for about twelve hours, or boils it in lime or alkali, or alkali with lime, and then soaks it in acid, as he uses soaps of resin in other mixtures—the alkalies being from 5° to 5° Tw., 1015°—1025° specific gravity.
2. Boils in a similar alkaline solution.
3. Washes.
4. Puts it into a solution of soda, of 3° Tw., 1023° specific gravity, adding chloride of soda until it rises up to from 6°—7° Tw. It is allowed to remain in this solution for some hours, and it is better if subjected to heating or squeezing between rollers, as in the washing machine.
5. He then soaks, sores, and washes.
6. He then puts it a second time into the solution of alkali and chloride.
7. Then washes, and boils again with soda. These operations, 6 and 7, may be repeated until the cloth becomes almost white.

The amount of exposure on the grass by this process is said to be not more than from one-half to one-fourth that required by the usual method, or it may be managed so as entirely to supersede croeting.

Chevalier Clausen has opened up the filaments of flax by the evolution of gas from a carbonate in which the plant is steeped, and at the same time bleached by chloride of magnesia.

**Bleaching of Materials for Paper.**

The bleaching of paper is conducted on the same principle as the bleaching of cotton. Paper is made principally of two materials, cotton and flax, generally mixed. The cotton waste of the mills, which is that inferior portion which has become too impure for spinning, or otherwise deteriorated, and cotton rags, are the principal, if not the only, sources of the cotton used by paper-makers. The waste is sorted by hand, the hard and soft being separated, and all accidental mixtures which occur in it are removed. This is done at first roughing on a large lattice, which is a frame of wire cloth, having squares of about three-quarters of an inch through which impurities may fall. It is then put into a duster, which is a long rectangular box, it may be ten feet long, lying horizontally, the inside diameter about two feet, and covered with wire gratings running horizontally, leaving openings of half an inch in width. As this revolves, the waste is thrown from one angle to the other, and throws out whatever dust or other material falls into the holes or spaces. The fibrous matter has little tendency to separate from the mass, which is somewhat agglutinated by being damp, chiefly from the oil obtained during the processes in the cotton mill. A second duster, however, is used to retain whatever may be of value; it is a kind of riddle. It is then transferred to the lattices, which are a series of boxes covered with wire gauze, the meshes of which are about half an inch square, and so arranged as to form a series of sorting tables. The sorting generally is done by young women. Each table has a large box or basket beside it into which the sorted material is thrown; this is removed when filled, by being pushed along a railroad or tramway. Pieces of stone, clay, leather, wood, nails, and other articles, are taken out. The cotton is then put into a devil similar to that which is used in cotton machinery, but having larger, stronger teeth, which tear it up into small fragments.

The rags are sorted according to quality, wooden carefully removed, and all the unavailable material sent back to the buyer. They are then chopped up by a knife, on the circumference of a heavy wheel, into pieces of an inch wide, devilled, and dusted.

The rags and the cotton waste are bleached in a similar manner. The cotton is put into kiers of about ten feet in diameter, of a kind similar to those described, and boiled with lime. The amount of lime used is about 6 lbs. to a cwt. of cotton or rags, but this varies according to the impurity. The lime removes a great amount of impure organic matter, and, as in bleaching, cotton cloth lays hold of the fatty matter, of which there is a great deal in the waste. When taken out, it is allowed to lie from two to three hours. The appearance is not much altered; it appears as impure as ever.

It is then put into the rag-engine and washed clean. This is a combined washing machine and filter, the invention of Mr. Wrigley, near Bury. The washing may last an hour and a half, or more.

The cotton has now a bright gray color, and looks moderately clean. It is full of water, which is removed by a hydraulic press, the cotton being put into an iron cylindrical box with perforated sides. It is then boiled in kiers or pulling boilers, where soda-ash is used, at the

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rate of 4 to 5 lbs. a cwt. Only as much water is used as will moisten the goods thoroughly. Much water would weaken the solution and render more soda necessary. It is then washed again in the rag-engine; afterwards put into chloride of lime, acidified as in cotton bleaching, and washed again in the rag-engine.

The cotton rags are treated in a similar manner. The colored rags are treated separately, requiring a different treatment according to the amount of color; this consists chiefly in a greater use of chloride of lime.

Some points relating to bleaching are necessarily treated of under Calico Painting.

BLEAK. (Cyprinus Alburnus.) The scales of this fish are used for making the essence of pearl, or essence d’orient, with which artificial pearls are manufactured. In the scales of the fish the optical effect is produced in the same manner as in the real pearl, the grooves of the latter being represented by the inequalities formed by the margins of the concentric laminae of which the scales are composed. These fish are caught in the Seine, the Loire, the Saone, the Rhine, and several other rivers. They are about four inches in length, and are sold very cheap after the scales are washed off. It is said that 4,000 fish are necessary for the production of a pound of scales, for which the fishermen of the Chaillonnais get from 18 to 25 livres.

The pearl essence is obtained merely by well washing the scales which have been scraped from the fish in water, so as to free them from the blood and mucilaginous matter of the fish.

BLENE (sulphide or sulphuret of zinc, "Black Jack") is a common ore of zinc, composed of zinc 67, sulphur 33; but it usually contains a certain proportion of the sulphide of iron, which imparts to it a dark color, whence the name of "Black Jack," applied to it by the Cornish miner. The ore of this country generally consists of zinc 61-3, iron 4-0, sulphur 35-6. Blende occurs either in a botryoidal form or in crystals, (often of very complex forms,) belonging to the tetrahedral division of the monomeric system. H = 3-5 to 4. Specific gravity = 3-9 to 4.—H. W. B.

In some districts the presence of the sulphide of zinc is regarded by the miners as a favorable indication, hence we have the phrase, "Black Jack rides a good horse." In other localities it is thought to be equally unfavorable, and the miners say, "Black Jack eats out the ore." For many years the English zinc ores were of little value, the immense quantity of zinc manufactured by the Vieille Montagne Company, and sent into this country, being quite sufficient to meet the demand. Beyond this, there was some difficulty in obtaining zinc which would roll into sheets, from the English sulphides. Although this has been to some extent overcome, most of the zinc obtained from blende is used in the manufacture of brass.

Bona has given the following analyses of varieties of blende:

<table>
<thead>
<tr>
<th>Sulphur</th>
<th>Zinc</th>
<th>Iron</th>
<th>Cadmium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carinthia</td>
<td>32·10</td>
<td>64·22</td>
<td>1·32</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>32·6</td>
<td>52·60</td>
<td>10·0</td>
</tr>
<tr>
<td>New Jersey</td>
<td>32·22</td>
<td>67·46</td>
<td>.</td>
</tr>
<tr>
<td>Tuscany</td>
<td>32·12</td>
<td>48·11</td>
<td>11·44</td>
</tr>
</tbody>
</table>

BLIND COAL, a name given to Anthracite.

BLOCK TIN. Metallic tin cast into a block, the weight of which is now about 3½ cwt. Formerly, when it was the custom to carry the blocks of tin on the backs of mules, the block was regulated by what was then considered to be a load for the mule, at 2½ cwt. Subsequently, the block of tin was increased in size, and made as much as two men could lift, or 3 cwt. It was the custom to order so many blocks of tin, and the smelter, being desirous of selling as much tin as possible, continued to increase the size of the block, so that, although 3½ cwt. is the usual weight, many blocks are sold weighing 3½ cwt.

BLOOD. Mr. Pillans, in 1854, took out a patent for the separation of the coloring matter of blood, and also for drying the prepared serous matters. He recommends the blood (which must be received warm) to be caught in shallow vessels containing from 14 lbs. to 20 lbs. of blood, to stand at rest from two to six hours according to the weather and the nature of the blood; then the clot is separated by a strainer from the scurvy fluid, and by means of cutting-knives, or rollers, the clot is divided into small pieces; a considerable quantity of coloring matter flows with the serum, which is to be set aside to deposit; the clot is placed on strainers until the serum has all drained away. By these operations there are obtained readily from the blood—1st, the clot, in a comparatively dry state, comprising hematosine, with a portion of serum and all the fibrine; 2d, a portion of serum, highly colored with hematosine; 3d, the clear serum.

The blood, in small fragments, is dried on wirework or trays, at a less temperature than will coagulate the hematosine, so that, when dry, it may be soluble in water; 110° to 115°
is the temperature recommended. The second or highly-colored serum can be dried by itself or mixed with the serum, and may be used for sugar refining and in dying.

The clear serum is dried and ground and in a fit state to be used as albumen, and may be employed by the printers of textile fabrics for fixing ultramarine blue and other colors, or as a substitute for egg albumen, both in printing colors and in refining liquids.

Instead of drying at once the clear serum, it may be mixed with 1/2 per cent. of oil of turpentine. Other vegetable, and, particularly, volatile oils, are also suitable, preferring those that have been exposed to the air; from 10 to 20 per cent. of water, ultramarine, suitable colors, or thickening, may be added, taking care that under no circumstance is it to be exposed to a heat high enough to coagulate it while in the drying-room.

BLOODSTONE. A very hard, compact variety of hematite iron ore, which, when reduced to a suitable form, fixed into a handle, and well polished, forms the best description of burnisher for producing a high lustre on gilt coat-buttons. The gold on china is burnished by the same means.—Knight.

Bloodstone is a name also applied to the jasper variety of quartz known as the heliotrope, colored deep-green, with interspersed blood-red spots like drops of blood—Dana.

BLOWPIPE. The blowpipe is so extremely useful to the manufacturer and to the miner that an exact description of the instrument is required. When we propel a flame by means of a current of air blown into or upon it, the flame thus produced may be divided into two parts, as possessing different properties—that of reducing under one condition and of oxidizing under another.

The reducing flame is produced by blowing the ordinary flame of a lamp or candle simply aside by a weak current of air impinging on its outer surface; it is therefore unchanged except in its direction. Unconsumed carbon, at a white heat, giving the yellow color to the flame, coming in contact with the substance, aids in its reduction.

The oxidizing flame is formed by pouring a strong blast of air into the interior of the flame; combustion is thus thoroughly established, and if a small fragment of an oxidizable body is held just beyond the point of the flame, it becomes intensely heated, and, being exposed freely to the action of the surrounding air, it is rapidly oxidized.

The best form of blowpipe is the annexed, (fig. 66,) which, with the description, is copied from Blandford's excellent translation of Dr. Theodore Scheerer's "Introduction to the Use of the Mouth Blowpipe."

The tube and nozzle of the instrument are usually made of German silver, or silver with a platinum point, and a trumpet-shaped mouth-piece of horn or ivory. Many blowpipes have no mouth-pieces of this form, but are simply tipped with ivory, or some similar material. The air-chamber A serves in some degree to regulate the blast and receives the stem, n, and the nozzle, a, which are made separately, and accurately ground into it, so that they may be put together, or taken apart at pleasure. The point b is best made of platinum, to allow of its being readily cleaned, and is of the form shown in the wood-cut. When the instrument is used, the mouth-piece is pressed against the lips, or, if this is wanting, the end of the stem must be held between the lips of the operator. The former mode is far less wearying than the latter; and whereas, with the trumpet mouth-piece, it is easy to maintain a continued blast for five or ten minutes, without it it is almost impossible to sustain an unbroken blast of more than two or three minutes' duration. While blowing, the operator breathes through his nostrils only, and, using the epiglottis as a valve, forces the air through the blowpipe by means of the cheek muscles.

Some years since, Mr. John Prideaux, of Plymouth, printed some valuable "Suggestions" for the use of the blowpipe by working miners. Some portions of this paper appear so useful, especially under circumstances which may preclude the use of superior instruments, &c., that it is thought advisable to transfer them to these pages.

For ordinary metallurgical assays, the common blowpipe does very well. A mere tapering tube, 10 inches long, ½ inch diameter at one end, and the opening at the other scarcely equal to admit a pin of the smallest kind, the smaller end curved off for 1 ½ inch to a right angle. A bulb at the bend, to contain the vapor condensed from the breath, is useful in long operations, but may generally be dispensed with. In selecting the blowpipe, the small
aperture should be chosen perfectly round and smooth, otherwise it will not command a
good flame.

A common candle, such as the miner employs under ground, answers very well for the
flame.

To support the subject of assay, or "the assay," as it has been happily denominated by
Mr. Children, two different materials are requisite, according as we wish to calcine or re-
duce it. For the latter purpose, nothing is so good as charcoal; but that from oak is less
calculable, both from its inferior combustibility and from its containing iron, than that from
alder, willow, or other light woods.

For calculation, a very convenient support, where platinum wire is difficult to procure,
is white-baked pipe-clay or china clay, selecting such as will not fuse nor become colored by
roasting with borax.

These supports are conveniently formed by a process of Mr. Tennant. The clay is to be
beaten to a smooth stiff body; then a thin cake of it, being placed between a fold of writing
paper, it is to be beaten out with a mallet to the thickness of a wafer, and cut, paper and
all, into squares of \( \frac{1}{2} \) inch diameter, or triangles about the same size. These are to be put
in the bowl of a tobacco-pipe, and heated gently till dry, then baked till the paper is burnt
away, and the clay left perfectly white. They should be baked in a clear fire, to keep out
coal-dust and smoke as much as possible, as either of these adhering to the clay plates
would color the borax in roasting. A small fragment of the bowl of a new tobacco-pipe
will serve instead in the absence of a more convenient material.

A simple pair of forceps, (fig. 67), to move and to take up the hot assay, may be made
of a slip of stiff tin plate, 8 inches long, \( \frac{1}{3} \) inch wide in the middle, and \( \frac{1}{16} \) inch at the
ends. The tin being rubbed off the points on a rough whetstone, the slip is to be bent until they approach each
other within \( \frac{1}{4} \) an inch, and the two sides are parallel; thus there will be spring enough in the forceps to open
and let go the assay when not compressed upon it by the
finger and thumb.

A magnetic needle, very desirable to ascertain the presence of iron, is easily made of
the requisite delicacy where a magnet is accessible. A bit of thin steel wire, or a long fine
stocking-needle, having \( \frac{1}{16} \) inch cut off at the point, is to be heated in the middle that it
may be slightly bent there, (fig. 68.) While hot, a bit of sealing-wax is to be attached to
the centre, and the point which had been cut off, being heated at the thick end, is to be fixed in the sealing-wax, so that the
sharp end may serve as a pivot, descending about \( \frac{1}{2} \) inch below the centre, taking care that the ends of the needle fall enough
below the pivot, to prevent it overturning. It must be mag-
netized, by sliding one end of a magnet half a dozen or more
times from the centre to one end of the needle, and the other
each a similar number of times from the centre of the needle to
its other end. A small brass thimble (not capped with iron) will do for the support, the
point of the pivot being placed in one of the indentations near the centre of the tap, when,
if well balanced, it will turn until it settles north and south. If one side preponderate,
it must be ripped until the balance be restored.

A black gun-flint is also occasionally used to rub the metallic globules, (first attached,
while warm, to a bit of sealing-wax,) and ascertain the color of the streak which they give.
Thus minute particles of gold, copper, silver, &c., are readily discriminated. A little refined
borax and carbonate of soda, both in powder, will complete the requisites.

Having collected these materials, the next object for the operator is to acquire the
faculity of keeping up an uninterrupted blast through the pipe whilst breathing freely
through the nose.

A very sensitive, and, for most purposes, sufficiently delicate balance, (fig. 69,) was
also devised by Mr. Prideaux, of which the following is a description:

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The common marsh reed, growing generally in damp places throughout the kingdom,
will yield straight joints, from 8 to 12, or more, inches long; an 8-inch joint will serve, but
the longer the better. This joint is to be split down its whole length, so as to form a
BLUE COPPERAS, OR BLUE STONE. 165

through, say $\frac{1}{4}$ inch wide in the middle, narrowed away to $\frac{1}{4}$ inch at the ends. A narrow slip of writing paper, the thinner the better, (bank post is very convenient for the purpose,) and as long as the reed trough, is to be stuck with common paste on the face of a carpenter's rule, or, in preference, that of an experimenter,—as the inches are divided into tenths instead of eighths;—in either case observing that the divisions of the inch on the rule be left uncovered by the paper. When it is dry, lines must be drawn the whole length of it, $\frac{1}{4}$ inch apart, to mark out a stripe $\frac{1}{4}$ inch wide. Upon this stripe the divisions of the inch are to be ruled off by means of a small square.

The centre division being marked 0, it is to be numbered at every fourth line to the ends. Thus the fourth from the centre on each side will be 10; the eighth, 20; the twentieth, 30; the sixteenth, 40, &c.; and a slip of 10 inches long, graduated into tenths of an inch, will have on each arm 50 lines, or 125 degrees, divided by these lines into quarters.

While the lines and numbers are drying, the exact centre of the reed-trough may be ascertained, and marked right across, by spots on the two edges. A line of gun water, full $\frac{1}{4}$ inch wide, is then laid with a camel-hair pencil along the hollow, and the paper being stripped from the rule, (which it leaves easily,) the graduated stripe is cut out with scissors, and laid in the trough, with the line 0 exactly in the centre. Being pressed to the gummed read, by passing the round end of a quill along it, it graduates the trough from the centre to each end. This graduation is very true, if well managed, as the paper does not stretch with the gun water after being laid on the rule with the paste.

A very fine needle is next to be procured, (those called bond-needles are the finest, and passed through a slip of cork the width of the centre of the trough, about $\frac{1}{4}$ inch square, $\frac{1}{4}$ thick. It should be passed through with care, so as to be quite straight. The cork should then be cut until one end of it fits into the trough, so that the needle shall bear on the edges exactly in the spots that mark the centre, as it is of importance that the needle and the cork shall rest at right angles with each other. The cork is now to be fixed in its place with gun water, and, when fast dry, to be soldered down on each side with a small portion of any soft resinous cement, on the point of a wire or knitting-needle; a little cement being also applied in the same manner to the edges of the cork where the needle goes through, to give it firmness, the beam is finished. It may be balanced by paring the edges on the heaviest side: but accurate adjustment is needless, as it is subject to vary with the dampness or the dryness of the air.

The support on which it plays is a bit of tin plate, (or, in preference, brass plate,) $\frac{1}{2}$ inch long, and 1 inch wide. The two ends are turned up square $\frac{1}{2}$ of an inch, giving a base of $\frac{1}{2}$ of an inch wide, and two upright sides $\frac{1}{2}$ high. The upper edges are then rubbed down smooth and square upon a Turkey stone, letting both edges bear on the stone together, that they may exactly correspond. For use, the beam is placed evenly in the support, with the needle resting across the edges. Being brought to an exact balance by a bit of writing paper, or any other substance, placed on the lighter side, and moved toward the end until the equilibrium is produced, it will turn with extreme delicacy, a bit of horseshair, $\frac{1}{4}$ inch long, being sufficient to bring it down freely.

It must not be supposed that any such instrument as this is recommended as in any way substituting the beautiful balances which are constructed for the chemist, and others requiring to weigh with great accuracy. The object is merely to show the miner a method by which he may construct for himself a balance which shall be sufficiently accurate for such blowpipe investigations as it may be important for him to learn to perform for himself. If the suggestions of the chemist who devised the above balance had been carried out, much valuable mineral matter which has been lost might have been turned to profitable account.

The blowpipe is largely used in manufactures, as in soldering, in hardening and tempering small tools, in glass-blowing, and in enamelling. In many cases the blowpipes are used in the mouth, but frequently they are supplied with air from a bellows moved by the foot, by vessels in which air is condensed, or by means of pneumatic apparatus.

Many blowpipes have been invented for the employment of oxygen and hydrogen, by the combustion of which the most intense heat which we can produce is obtained. Professor Hare, of Philadelphia, was the first to employ this kind of blowpipe, when he was speedily followed by Clark, Gurney, Leeson, and others. The blowpipe, fed with hydrogen, is employed in many soldering processes with much advantage.

The general form of the "workshop blowpipe" is that of a tube open at one end, and supported on trunnions in a wooden pedestal, so that it may be pointed vertically, horizontally, or at any angle as desired. Common street gas is supplied through one hollow trunnion, and it escapes through an annular opening, while common air is admitted through the other trunnion, which is also hollow, and is discharged in the centre of the hydrogen through a central conical tube; the magnitude and intensity of the flame being determined by the relative quantities of gas and air, and by the greater or less protrusion of the inner cone, by which the annular space for the hydrogen is contracted in any required degree.—Holtsapfel.

BLUE COPPERAS, OR BLUE STONE. The commercial or common names of the sulphate of copper. See Copper.
BLUE VITRIOL.  

SUlPHATE of CUPPER. When found in nature, it is due entirely to the decomposition of the sulphides of copper, especially of the yellow copper pyrites, which are liable to this change when placed under the influence of moist air, or of water containing air.

BOGHEAD COAL, and other Brown Cannel Coals. The brown cannel is chiefly confined to Scotland, and have been wrought, with the exception of the celebrated Boghead, for the last thirty years. They are found at Boghead, near Bathgate; Rocksoles, near Airdrie; Pirnie, or Methill; Capeldrea, Kirkness, and Wemyss, in Fife. The first-named coal, about which there has been so much dispute as to its nature, has only been in the market eight years. It is considered the most valuable coal hitherto discovered for gas and oil-making purposes; but, strange to say, the middle portion of the Pirnie, or Methill seam, which has been unnoticed for thirty years, is nearly as valuable for both purposes.

BOGHEAD. Amorphous; fracture subconchoidal, compact, containing impressions of the stems of Sigillaria, and its roots, (Stiguamaon,) with rootlets traversing the mass. Color, clove-brown, streak yellow, without lustre; a non-electric; takes fire easily, splits, but does not fuse, and burns with an empyreumatic odor, giving out much smoke, and leaving a considerable amount of white ash. II. 25. Specific gravity, 1-290.

According to Dr. Stenhouse, F. R. S., its composition is:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>65-72</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>9-03</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0-72</td>
</tr>
<tr>
<td>Oxygen</td>
<td>4-78</td>
</tr>
<tr>
<td>Ash</td>
<td>19-75</td>
</tr>
</tbody>
</table>

Total: 100-00

Dr. Stenhouse's analysis of the ash of Boghead coal, from three analyses, was as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>58-31</td>
</tr>
<tr>
<td>Alumina</td>
<td>33-65</td>
</tr>
<tr>
<td>Sesquioxide of iron</td>
<td>7-30</td>
</tr>
<tr>
<td>Potaish</td>
<td>0-84</td>
</tr>
<tr>
<td>Soda</td>
<td>0-41</td>
</tr>
<tr>
<td>Lime and sulphuric acid</td>
<td>traces.</td>
</tr>
</tbody>
</table>

Dr. Andrew Fyfe, F. R. S. E., on analysis, found that the coal yielded, from a picked specimen, 70 per cent. of volatile matter, and 30 per cent. of coke and ash. From a ton he obtained 14-880 cubic feet of gas, the illuminating power of which was determined by the use of the Bunsen photometer, the gas being consumed by argands burning from 2½ to 3½ feet per hour, according to circumstances. The candle referred to was a spermaceti candle, burning 140 grains per hour.

<table>
<thead>
<tr>
<th>Cubic Feet of Gas per Ton of Coal</th>
<th>Specific Gravity</th>
<th>Condensation by Chlorine in 100 Parts</th>
<th>Durability 1 foot barns.</th>
<th>Illuminating Power 1 foot= Light of Candles.</th>
<th>Pounds of Coke per Ton of Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>802</td>
<td>27</td>
<td>88 25</td>
<td>7-72</td>
<td>760</td>
</tr>
</tbody>
</table>

The Pirnie or Methill brown cannel, on analysis, gives the following results:

- Specific gravity: 1-126
- Gas per ton: 13,500 feet.
- Illuminating power: 28 candles.
- Coke and ash: 36 per cent.
- Hydro-carbons condensed by bromine: 20
- Sulphuretted hydrogen: ½
- Carbonic acid: 4
- Carbonic oxide: 74
- Volatile matter in coal: 65
- Specific gravity of gas: 700

The Boghead coal occurs in the higher part of the Scotch coal field; in about the position of the "slaty band" of ironstone, its range is not more than 3 or 4 miles in the lands of Torbane, Ischeros, Boghead, Capper's, and Bathvale, in the county of Linlithgow. In thickness it varies from 1 to 30 inches, and at the present consumption, say from 80,000 to 100,000 tons per annum, it cannot last many years.
The following section of a pit at Torbane shows that the cannel occurs in ordinary coal measures, and under circumstances common to beds of coal:

<table>
<thead>
<tr>
<th>Boghead house coal</th>
<th>Ft.</th>
<th>In.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arenaceous shale</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Silty sandstone</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Shale and ironstone, containing remains of plants and shells</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Conquet stone (impure ironstone)</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Boghead cannel</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Fire clay, full of Stigmariae</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Coal (common)</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Black shale</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Coal</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Shale</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Coal</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Fire clay</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Hard shale</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Thin lamina of coal and shale</td>
<td>0</td>
<td>3.5</td>
</tr>
<tr>
<td>Common coal</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Fire clay</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

One of the chief characters of this cannel is its indestructibility under atmospheric agencies; for whether it is taken from the mine at a depth of fifty fathoms, or at the outcrop, its gas and oil-yielding properties are the same. Even a piece of the mineral taken out of the drift deposits, where it had most probably lain for thousands of years, appears to be in no way inferior in quality as if it had been but lately raised from the mine.

In the earth the seam lies parallel to its roof and floor, like other beds of coal; and it is traversed by the usual vertical joints, dividing it into the irregular eubes which so generally characterize beds of cannel. The roof lying above the cement stone contains remains of Calamites; and the ironstone nodules, fossil shells of the genus Unio. The floor of the mine contains Stigmariae; and the coal itself affords more upright stems of Sigillaria, and its roots (Stigmariae) and their radicles, running through the seam to a considerable distance, than the majority of coals show. In these respects it entirely resembles the Firnies or Methill seam. Most cannels afford remains of fish; but in Boghead no traces of these fossils have yet been met with, although they have been diligently sought after.

The roots in the floors, and the upright stems of trees in the seam itself, appear to show that the vegetable matter now forming the coal grew on the spot where it is found. If the mangroves and other aquatic plants, at the present day found growing in the black vegetable mud of the marine swamps of Bass town, on the west coast of Africa, were quietly submerged and covered up with clay and silt, we should have a good illustration of the formation of a bed of carbonaceous matter showing no structure, mingled with stems and roots of trees showing structure, which is the case of Boghead coal, the structure being only detected in those parts showing evidence of stems and roots, and not in the matrix in which those fossils are contained.

The chemical changes by which vegetable matter has been converted into Boghead cannel will not be here dwelt on; but the chief peculiarity about the seam is its close and compact roof, composed of cement stone and shale. This is perfectly water and air-tight, so much so that, although the mine is troubled with a great quantity of water, it all comes through the floor, and not the roof. This tight covering of the coal has doubtless exercised considerable influence on the decomposing vegetable matter after the latter had been submerged. It is worthy of remark, that, above the Firnies or Methill seam,—the coal nearest approaching Boghead,—a similar bed of impure ironstone occurs.

Away from whin dykes which traverse the coal field, there are no appearances of the action of an elevated temperature, either upon the coal or its adjoining strata, to give any sanction to the hypothesis that the cannel has resulted from the partial decomposition of a substratum of coal by the heat of underlying trap, the volatile matters having been retained in what has probably been a bed of shale. First, it must be understood that Boghead cannel, even when treated with boiling naphtha, affords scarcely a trace of bitumen; and, secondly, when the seam of coal is examined in the neighborhood of a whin dyke, where heat has evidently acted on it, it is found nothing like cannel, but as a soft sticky substance, of a brown color, resembling burnt Indian-rubber. Besides these facts, the seams of coal and their accompanying strata, both above and below the cannel, show no signs of the action of heat, but, on the contrary, exhibit every appearance of having been deposited in the usual way, and of remaining without undergoing any particular alteration. —E. W. B.

**BOGHEAD NAPHTHA, (syn. Bathgate naphtha,) naphtha from the Boghead coal. See NAPHTHA, BOGHEAD.**

**BOG IRON ORE** is an example of the recent formation of an ore of iron, arising from the decomposition of rocks, containing iron, by the action of water charged with carbouic
add. The production of this ore of iron in the present epoch, explains to us many of the conditions under which some of the more ancient beds of iron ore have been produced.

Bog iron ore is common in the peat bogs of Ireland and other places. The iron manufactured from bog iron ore is what is called "cold short," from the presence of phosphorus; it cannot, therefore, be employed in the manufacture of wire, or of sheet iron; but, from the fluidity of the metal, it is valuable for casting.

It varies much in composition, some specimens giving 30 and others 70 per cent. of the peroxide of iron. Protosilicate of iron and oxide of manganese are often present; and as much as 10 per cent. of phosphorus and organic matter have been detected. See Iron.

BOILER. See Boilers, vol. 1.

BOLE. A kind of clay, often highly colored by iron. It usually consists of silic, alumina, iron, lime, and magnesia. It is not a well-defined mineral, and, consequently, many substances are described by mineralogists as bole.

Armenian bole is of a bright red color. This is frequently employed as a dentifrice, and in some cases it is administered medicinally.

Bole of Böis is yellow, contains carbonate of lime, and effervescences with acids. Bohemian bole is a yellowish red. French bole is of a pale red, with frequent streaks of yellow. Lorraine bole and Silicium bole are, in most respects, similar to the above-named varieties.

The following analysis are by C. Van Hauer:

Capo di Bove—Silica, 45.04; alumina, 29.53; peroxide of iron, 8.88; lime, 0.60; magnesia, a trace; water, 14.27 = 98.72.

New Holland—Silica, 38.28; alumina, 31.00; peroxide of iron, 11.00; lime, a trace; magnesia, a trace; water, 18.81 = 99.08.

BOLOGNIAN STONE. A sulphate of barytes, found in smooth masses, which phosphoresces when, after calcination, it is exposed to the solar rays.

BOMBAZINE. A worsted stuff mixed with silk; it is a twilled fabric, of which the warp is silk and the weft worsted.

BOMBYX MOLI. The moth to which the silkworm turns. This species was originally brought from China. In this country the eggs of this moth are hatched early in May. The caterpillar (silkworm) is at first of a dark color; but gradually, as with all other caterpillars, it becomes lighter colored. This worm is about eight weeks in arriving at maturity, during which time it frequently changes its color. When full grown, the silkworm commences spinning its web in some convenient place. The silkworm continues drawing its thread from various points, and attaching it to others; it follows, therefore, that, after a time, the body becomes, in a great measure, enclosed in the thread. The work is then continued from one thread to another, the silkworm moving its head and spinning in a zigzag way, bending the fore part of the body back to spin in all directions within reach, and shifting the body only to cover with silk the part which was beneath it. As the silkworm spins its web by thus bending the fore part of the body back, and moves the hinder part of the body in such a way only as to enable it to reach the farther back with the fore part, it follows that it encloses itself in a cocoon much shorter than its own body; for soon after the beginning, the whole is continued with the body in a bent position. During the time of spinning the cocoon, the silkworm decreases in length very considerably; and after it is completed it is not half its original length; at this time it becomes quite torpid, soon changes its skin, and appears in the form of a chrysalis. The time required to complete the cocoon is five days. In the chrysalis state the animal remains from a fortnight to three weeks; it then bursts its case, and comes forth in the inago state, the moth having previously dissolved a portion of the cocoon by means of a fluid which it ejects.—Penny Magazine.

BON-BONS. Comfits and other sweetmeats of various descriptions pass under this name. A large quantity is regularly imported from France into this country, and, from its usually superior quality, it is much in request. The manufacture of sweetmeats, confectionary, &c., does not enter so far into the plan of this work as to warrant our giving any special detail of the various processes employed.

Liqueur Bonbons are made in the following manner:—A syrup evaporated to the proper consistence is made, and some alcoholic liqueur is added to it. Plaster of Paris models of the required form are made; and these are employed, several being fastened to a rod, for the purpose of making moulds in powdered starch, filling shallow trays. The syrup is then, by means of a funnel, poured into these moulds, and there being a powerful repulsion between the starch and the alcoholic syrup, the upper portion of the fluid assumes a spherical form; then some starch is sifted over the surface, and the mould is placed in a warm closet. Crystallization commences on the outside of the bon-bon, forming a crust inclosing the syrup, which constantly gives up sugar to the crystallizing crust until it becomes sufficiently firm to admit of being removed. A man and two boys will make three hundredweights of bon-bons in a day.
**BONES.**

**Crystallized Bon-bons** are prepared by putting them in shallow dishes, placed on shelves in the drying chamber, pieces of linen being stretched over the surface, to prevent the formation of a crust upon the surface of the fluid. In two or three days the bon-bons are covered with crystals of sugar; the syrup is then drained off, and the confections dried.

**Painted Bon-bons.**—Bon-bons are painted by being first covered with a layer of glazing; they are then painted in body colors, mixed with mucilage and sugar.

The French have some excellent regulations, carried out under the "**Préfet de Police,**" as to the colors which may be employed in confectionery. These are to the following effect:

"Considering that the coloring matter given to sweets, bon-bons, liqueurs, lozenges, &c., is generally imparted by mineral substances of a poisonous nature, which imprudence has been the cause of serious accidents; and, that the same character of accidents have been produced by chewing or sucking the wrapping paper of such sweets, it being glazed and colored with substances which are poisonous; it is expressly forbidden to make use of any mineral substance for coloring liqueurs, bon-bons, sugar-plums, lozenges, or any kind of sweetmeats or pastry. No other coloring matter than such as is of a vegetable character shall be employed for such a purpose. It is forbidden to wrap sweetmeats in paper glazed or colored with mineral substances. It is ordered that all confectioners, grocers, dealers in liqueurs, bon-bons, sweetmeats, lozenges, &c., shall have their name, address, and trade printed upon the paper in which the above articles shall be enclosed. All manufacturers and dealers are personally responsible for the accidents which shall be traced to the liqueurs, bon-bons, and other sweetmeats manufactured or sold by them."

If similar provisions were in force in this country, it would prevent the use, to an alarming extent, in our cheap confectionery, of such poisonous substances as

- Arsenite of copper,        Sulphide of arsenic,
- Acetate of copper,        Oxide of lead,
- Chromate of lead,         Sulphide of mercury, &c.

The coloring matters allowed to be used in France are indigo, Prussian blue, saffron, Turkey yellow, queretron, cochineal, Brazil wood, madder, &c.

**BONES.** Heintz found that the fixed bases in the bones were sufficient to saturate completely the acids contained in them, so that the phosphate of lime, as well as the phosphate of magnesia, which the bones contain, is composed, according to the formula $3\text{CaO} \cdot \text{PO}_4$.

Bone phosphate of lime was considered by Berzelius to be $5\text{CaO} \cdot 5\text{PO}_4$.

True bone structure is perfectly free from chlorides, from sulphates, and from iron; these salts being only found when the liquid pervading the bones has not been completely removed. The bones in youth contain less earthy constituents than those of adults; and, in advanced age, the proportion of mineral matters increases. Von Biria found more bone earth in the bones of birds than in those of mammals; he found also the ratio of the carbonate of lime to the phosphate to be generally greater. In the bones of amphibious, he found less inorganic matter than in those of mammals and birds; and, in the bones of fishes, the earthy matters vary from 21 to 57 per cent. The scales of fishes have a composition somewhat similar to that of bone, but they contain phosphate of lime in small quantity only.

In certain diseases, (the *eruinae of children,* the earthy salts fall in the spongy portion of the bone as low as 28-16 per cent. of the dry bone; and in several cases the proportion of earthy matter was found by Schlesberger as low as 50 per cent. At the age of 21 years, the weight of the skeleton is at that of the whole body in the ratio of $10:3:100$ in man, and in that of $8:5:100$ in woman, the weight of the body being about 125 or 130 lbs.

The quantity of organic matter in fossil bones varies very considerably: in some cases it is found in as large a quantity as in fresh bones, while in others it is altogether wanting. Carbonate of lime generally occurs in far larger quantity in fossil than in recent bones, which may arise from infiltration of that salt from without, or from a decomposition of a portion of the phosphate of lime by carbonic acid or carbonates. Magnesia often occurs in larger quantities in the fossil remains of vertebrated animals than in the fresh bones of the present animal world.

Liebig found in the cranial bones excavated at Pompeii a larger proportion of fluoride of calcium than in recent bones; while, on the other hand, Girardin and Preisser found that this salt had greatly diminished in bones which had lain long in the earth, and, in some cases, had even wholly disappeared.

The gelatinous tissue of bones was found by Von Biria to consist of

<table>
<thead>
<tr>
<th>Ox bones</th>
<th>Fossil bones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0:4-0:41</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>7:111</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>18:154</td>
</tr>
<tr>
<td>Oxygen</td>
<td>24:119</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0:216</td>
</tr>
</tbody>
</table>

This is the same composition as that of the gelatinous tissues.
In the arts, bones are employed by turners, cutlers, manufacturers of animal charcoal, and, when calcined, by assayers, for making cupsels. In agriculture, they are employed as a manure. Laid on in the form of dust, at the rate of 30 to 35 cwt. per acre, they have been known to increase the value of old pastures from 10s. or 15s. to 50s, or 60s. per acre; and after the lapse of 20 years, though sensibly becoming less valuable, had remained still worth two or three times the rent it paid before the bones were laid on. In the large dyeing establishments in Manchester, the bones are boiled in open pans for 24 hours, the fat skimmed off and sold to the candle makers, and the size afterwards boiled down in another vessel till it is of sufficient strength for stiffening the thick goods for which it is intended. The size liquor, when exhausted or no longer of sufficient strength, is applied with much benefit as a manure to the adjacent pasture and artificial grass lands, and the exhausted bones are readily bought up by the Lancashire and Cheshire farmers. When burned bones are digested in sulphuric acid diluted with twice its weight of water, a mixture of gypsum and acid phosphate of lime is obtained, which, when largely diluted with water, forms a most valuable liquid manure for grass land and for crops of rising corn; or, to the acid solution, pearl ashes may be added, and the whole then dried up, by the addition of charcoal powder or vegetable mould, till it is sufficiently dry to be scattered with the hand as a top dressing, or buried in the land by means of a drill.

In France, soup is extensively made by dissolving bones in a steam heat of two or three days' continuance. Respecting the nutritive property of such soup, Liebig has expressed the following strong opinion:—"Gelatine, even when accompanied by the savory constituents of flesh, is not capable of supporting the vital process; on the contrary, it diminishes the nutritive value of food, which it renders insufficient in quantity and inferior in quality, and it overloads the blood with nitrogenous products, the presence of which disturbs and impedes the organic processes." The erroneous notion that gelatine is the active principle of soap, arose from the observation that soap made, by boiling, from meat, when concentrated to a certain point, gelatinizes. The jelly was taken to be the true soup until it was found that the best meats did not yield the finest gelatine tablets, which were obtained most beautiful and transparent from tendons, feet, cartilage, bones, &c. This led to an investigation on nutrition generally, the results of which proved that gelatine, which by itself is tasteless, and when eaten excites nausea, possesses no nutritive value whatever.

The following table exhibits the relation between the combustible animal matter and the mineral substances of bones, as found by different observers:

<table>
<thead>
<tr>
<th>Organic Portion</th>
<th>Inorganic Portion</th>
<th>Observers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ox bones</td>
<td>1 2-0</td>
<td>Berzelius.</td>
</tr>
<tr>
<td>Human bones</td>
<td>1 2-1</td>
<td>Marchand.</td>
</tr>
<tr>
<td>Bird bones</td>
<td>1 2-0</td>
<td>Berzelius.</td>
</tr>
<tr>
<td></td>
<td>1 1-8 to 2-2</td>
<td>Frerichs.</td>
</tr>
<tr>
<td></td>
<td>1 2-0 in mean</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 1-8 to 2-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 1-9 in mean</td>
<td>Von Bria.</td>
</tr>
<tr>
<td></td>
<td>1 2-3 to 2-6</td>
<td></td>
</tr>
</tbody>
</table>

Prior to the use of bones by the turner or carver, they require the oil with which they are largely impregnated, to be extracted, by boiling them in water, and bleaching them in the sun or otherwise. This process of boiling, in place of softening, robs them of part of their gelatine, and therefore of part of their elasticity and contractibility likewise, and they become more brittle.

The forms of the bones are altogether unfavorable to their extensive or ornamental employment; most of them are very thin and curved, contain large cellular cavities for marrow, and are interspersed with vessels that are visible after they are worked up into spoons, brushes, and articles of common turnery. The buttock and shin bones of the ox and calf are almost the only kinds used. To whiten the finished works, they are soaked in turpentine for a day, boiled in water for about an hour, and then polished with whitening and water.

Holtzapfl also informs us, that after the turning tool, or scraper, has been used, bone is polished, 1st, with glass paper; 2d, with Trent sand, or Flanders brick, with water on flannel; 3d, with whiting and water on a woollen rag; 4th, a small quantity of white wax is rubbed on the work with a quick motion; the wax fills the minute pores, but only a very minute portion should be allowed to remain on the work. Common bone articles, such as nail and tooth brushes, are frequently polished with slaked lime used wet on flannel or woolen cloth. See "On Bone and its Uses," by Arthur Aitken, Trans. of Society of Arts, 1832 and 1839.

The importance of the trade in bones will be seen from the following statement of Imports, in 1856, of the bones of animals and fish—not whalebone.
BONE BLACK.

<table>
<thead>
<tr>
<th>Country</th>
<th>Tons</th>
<th>Computed real Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>13,383</td>
<td>£68,588</td>
</tr>
<tr>
<td>Norway</td>
<td>878</td>
<td>4,500</td>
</tr>
<tr>
<td>Denmark</td>
<td>2,636</td>
<td>13,509</td>
</tr>
<tr>
<td>Prussia</td>
<td>826</td>
<td>4,335</td>
</tr>
<tr>
<td>Hanover</td>
<td>551</td>
<td>2,824</td>
</tr>
<tr>
<td>Hanse Towns</td>
<td>4,073</td>
<td>20,574</td>
</tr>
<tr>
<td>Holland</td>
<td>4,423</td>
<td>22,822</td>
</tr>
<tr>
<td>France</td>
<td>881</td>
<td>4,515</td>
</tr>
<tr>
<td>Spain</td>
<td>777</td>
<td>3,982</td>
</tr>
<tr>
<td>Tuscany</td>
<td>787</td>
<td>4,033</td>
</tr>
<tr>
<td>Two Sicilies</td>
<td>901</td>
<td>4,618</td>
</tr>
<tr>
<td>Austrian Italy</td>
<td>1,968</td>
<td>10,086</td>
</tr>
<tr>
<td>Turkey Proper</td>
<td>857</td>
<td>4,592</td>
</tr>
<tr>
<td>United States</td>
<td>583</td>
<td>3,019</td>
</tr>
<tr>
<td>Brazil</td>
<td>7,512</td>
<td>40,056</td>
</tr>
<tr>
<td>Uruguay</td>
<td>15,457</td>
<td>79,317</td>
</tr>
<tr>
<td>Buenos Ayres</td>
<td>9,356</td>
<td>50,329</td>
</tr>
<tr>
<td>Australia</td>
<td>897</td>
<td>4,389</td>
</tr>
<tr>
<td>Other parts</td>
<td>3,347</td>
<td>17,154</td>
</tr>
<tr>
<td></td>
<td>70,949</td>
<td>£263,813</td>
</tr>
</tbody>
</table>

In 1857, of bones, whether burnt or not, or as animal charcoal, 83,951 tons.—H. M. N.

BONE BLACK. The composition of perfectly dry bone black of average quality is as follows:—Phosphate of lime, with carbonate of lime, and a little sulphuret of iron, or oxide of iron, 88 parts; iron in the state of siliculated carburet, 2 parts; charcoal containing about \( \frac{1}{15} \) of nitrogen, 10 parts. None of the substances present, except the charcoal, possess separately any decolorizing power.

It was formerly supposed that the peculiar absorbing and decolorizing power of animal charcoal was only exerted towards bodies of organic origin; but it was found, by Graham, that inorganic substances are equally subject to this action; and later experiments have demonstrated that there are few, if any, chemical compounds which altogether resist the absorbing power of charcoal. The action is of a mechanical nature, and in some cases it is sufficiently powerful to overcome chemical affinities of considerable power. It is not confined to charcoal, though pre-eminent in this substance, in consequence of the immense extent of surface which its porous structure presents. The action of charcoal in sugar refining has been particularly studied by Liidersdorf. When the decocted saccharine juice is allowed to flow upon a moist and firmly compressed charcoal filter, pure water is the first product that passes through; but a considerably larger quantity is obtained than was employed for moistening the charcoal. Water is then obtained of a decidedly saline character, which increases in strength, and after this has passed through for some time, a sweet taste becomes perceptible, which gradually increases, and at last entirely masks the saline. This purely sweet fluid continues to flow for some time; after which, the liquid acquires an alkaline reaction from the presence of caustic lime; it then becomes colored, the liquid getting gradually darker, till the action of the charcoal ceases. Lime is completely abstracted from lime water by bone charcoal; and, according to the experiments of Chevalier, lead salts are likewise entirely absorbed, the acetate the most readily. It has also been shown by Graham, that iodine even is separated from iodine of potassium. The commercial value of animal charcoal has usually been estimated by its decoloring power on sulphate of indigo; its absorbent power, which is a property of equal, perhaps of greater importance, may, according to M. Corewinder, be determined, approximatively, by the quantity of lime which a given weight will absorb. For this purpose he employs a solution of saccharate of lime of known strength. An acid liquor is first prepared, composed of 20 grammes of pure oil of vitriol diluted with water to exactly 1 litre. A solution of saccharate of lime is then prepared, by dissolving 125 to 130 grammes of white sugar in water, adding thereto 15 to 20 grammes of quick-lime, boiling the liquid, and then filtering to separate the undissolved lime. This solution is prepared of such a nature, that it will be exactly saturated by the same volume of the dilute sulphuric acid. By adding the latter to 50 cubic centimetres of the liquid filtered from the animal charcoal, it is easy to see how many degrees of the burette are required to complete the saturation of the lime. Suppose 53 are required for this purpose, 100 — 53 = 47, which represent the proportion of lime absorbed by the charcoal; this is, therefore, the number representing the standard. By operating with a burette graduated from the bottom, the degree of the charcoal experimented upon may be read directly.
BOOKBINDING. The process of sewing together the sheets of a book, and securing them with a back and side boards.

Books are said to be either stitched, or in boards, or half-bound, or bound. The first consists simply of stitching the sheets together. The second, of placing the sheets, after they have been stitched, between millboard sides, which are covered with paper or cloth, and with the backs lettered and ornamented. The third is a process of more perfectly securing the leaves, and of placing them between boards with a back of leather, the side-boards being covered with suitable paper. Books are wholly covered with leather. Bookbinding is performed in the following manner:—The sheets are first folded into a certain number of leaves, according to the form in which the book is to appear, as follows:

The folio consists of —— 2 leaves
" quarto of —— 4 "
" octavo of —— 8 "
" duodecimo of —— 12 "

When the leaves are thus folded and arranged in proper order, they are, if the books have been long printed, usually beaten upon a stone with a heavy hammer, to make them solid and smooth, and are then subjected to severe pressure in a powerful press; but in the case of newly-written books, pressure alone is considered sufficient. Boating, or severe pressure, would spoil the book; because the ink, not being well dried, would "set off" on the opposite pages.

The employment in bookbinding of a rolling-press for smoothing and condensing the leaves, instead of the hammering which books have usually received, is an improvement introduced several years ago in the trade by Mr. W. Burn. His press consists of two iron cylinders about a foot in diameter, adjustable in the usual way by means of a screw, and put in motion by the power of one man, or of two if need be, applied to one or two winch-handles. In front of the press sits a boy who gathers the sheets into packets, by placing two, three, or four upon a piece of tin plate of the same size, and covering them with another piece of tin plate, and thus proceeding by alternating tin plates and bundles of sheets till a sufficient quantity has been put together, which will determine the thickness of the paper. The packet is then passed between the rollers and received by the man who turns the winch, and who has time to lay the sheets on one side and to hand over the tin plates by the time that the boy has prepared a second packet. A mission Bible may be passed through the press in one minute, whereas the time necessary to beat it would be twenty minutes. It is not, however, merely a saving of time that is gained by the use of the rolling-press; the paper is made smoother than it would have been by beating; and the compression is so much greater, that a rolled book will be reduced to about five-sixths of the thickness of the same book if beaten. A shelf, therefore, that will hold fifty books bound in the usual way, would hold nearly sixty of those bound in this manner—a circumstance of no small importance, when it is considered how large a space even a moderate library occupies, and that book-cases are expensive articles of furniture. The rolling-press is now substituted for the hammer by our principal bookbinders.

After the sheets have been thus prepared, they are sewed; for which purpose the sewing machine is employed. See Bookbinding, Vol. I.

BORACIO ACID. (Acide Borique, Fr. BO₃; chemical equivalent, 34.9; specific gravity, 1.93.) Suppose to be the chrysocolla of Pliny. In the seventh century, Geber mentions borax; and it was described by Geoffroy and by Baron in the early part of the eighteenth century. Boracic acid was formerly called Howbery's redactive salt.

This acid occurs in several minerals, particularly as tincal, or crude borbate of soda, which is found in the form of incrustations in the beds of small lakes in Thibet, where it is dug up during the hot season. Sassolin, so called from its having been first obtained from one of the localities in Tuscany named Sasso, is native boracic acid. It is found abundantly in the crater of Vulcano, one of the Lipari Islands, forming a layer on the sulphur and around the fumaroles, or exits, of the sulphurous exhalations. The native stalactitic salt, according to Klaproth, contains mechanically mixed sulphate of magnesia and iron, sulphate of lime, silica, carbonate of lime, and alumina. Erdmann has stated that sassolin contains 3.18 per cent. by weight of ammonia, and, instead of being pure boracic acid, that it is a borate of ammonia. Native boracic acid is composed of boracic acid, 96.4 per cent.; water, 4.6 per cent. E. D. Larderel.

Professor Graham, in his "Report on the Chemical Products of the Great Exhibition of 1851," thus speaks of Larderel's discovery:—

"The preparation of boracic acid by Count F. de Larderel, of Tuscany, was rewarded by a Council medal. Although this well-known manufacture is not recent, having attained its full development at least ten years, still the bold originality of its first conception, the perseverance and extraordinary resources displayed in the successful establishment, and the value of the product which it supplies, will always place the operations of Count de Larderel}
among the highest achievements of the useful arts, and demand the most honorable mention at this epoch. The vapor issuing from a volcanic soil is condensed, and the minute proportion of boracic acid which it contains (not exceeding 0° per cent.) is recovered by evaporation, in a district without fuel, by the application of volcanic vapor itself as a source of heat. The boracic acid thus obtained greatly exceeds in quantity the old and limited supply of borax from the upper districts of India, and has greatly extended the use of that salt in the glazes of porcelain, and recently in the making of the most brilliant crystal, when combined with the oxide of zinc instead of oxide of lead."—Reports of the Jurors of the Great Exhibition of 1851.

The violence with which the scalding vapors escape from the sufiioni gives rise to muddy explosions when a lake has been drained by turning its waters into another lake. The mud is then thrown out, as solid matters are ejected from volcanoes, and there is formed in the bottom of the lake a crowd of little cones of eruption, whose temperatures when in activity and play are generally from 120° to 145° C, and the clouds which they form in the lagoons constitute true natural barometers, whose greater or less density rarely disappoints the predictions that they announce to the inhabitants of those lagoons.

The boracic acid of the Tuscan lagoons is obtained from nine different works belonging to Count Larderel, the produce of which is on the average as follows:—

<table>
<thead>
<tr>
<th>Place</th>
<th>Boracic Acid (lbs.) per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sasso</td>
<td>36,000</td>
</tr>
<tr>
<td>Larderello</td>
<td>32,700</td>
</tr>
<tr>
<td>Lervazano</td>
<td>20,270</td>
</tr>
<tr>
<td>Monte Corboli</td>
<td>19,125</td>
</tr>
<tr>
<td>Castel Nuovo</td>
<td>14,570</td>
</tr>
<tr>
<td>Monte Rotondo</td>
<td>16,850</td>
</tr>
<tr>
<td>San Frederigo</td>
<td>9,000</td>
</tr>
<tr>
<td>Lustignano</td>
<td>7,640</td>
</tr>
<tr>
<td>Lago</td>
<td>5,400</td>
</tr>
</tbody>
</table>

165,855 avoirdupois pounds.

M. Payen has given the following as the composition of this crude boracic acid for 100 kilogrammes:

- Pure crystallized boracic acid: 74 to 84
- Sulphate of ammonia
  - " of magnesia: 14 to 8
  - " of lime
- Chloride of iron:
- Alumina
- Sand, &c.
- Sulphur: 2.2 to 1.35
- Hygroscopic water disengaged at 35° C: 7 to 57.5
- Azotic organic matter
- Hydrochlorate of ammonia
- Hydrochloric and hydro sulphuric acid: 2.7 to 1

The processes of chemical alteration taking place beneath the crater of Vulcano, already spoken of, may, according to the statement of Hoffmann, depend upon conditions very similar to those existing in Tuscany. There, likewise, sulphuretted hydrogen is associated with the boracic acid, and, it would appear, in much greater quantity, since the fissures through which the vapor issues are thickly lined with sulphur, which is in sufficient quantity to be collected for sale. A profitable factory is established at the place, which yields daily, besides boracic acid and chloride of ammonium, about 1,700 lbs. of refined sulphur, and about 600 lbs. of pure alum.—Bischoff.

In 1855 our Imports were:

<table>
<thead>
<tr>
<th>Country</th>
<th>Cwts</th>
<th>Computed real Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boracic acid from Sardinia</td>
<td>85</td>
<td>£383</td>
</tr>
<tr>
<td>&quot; Tuscany</td>
<td>26,777</td>
<td>121,183</td>
</tr>
<tr>
<td>&quot; Gibraltar</td>
<td>247</td>
<td>4,285</td>
</tr>
</tbody>
</table>

Total: 27,809 £125,831

And in 1856:

<table>
<thead>
<tr>
<th>Country</th>
<th>Cwts</th>
<th>Computed real Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boracic acid from Sardinia</td>
<td>815</td>
<td>£8,177</td>
</tr>
<tr>
<td>&quot; Tuscany</td>
<td>25,063</td>
<td>110,264</td>
</tr>
<tr>
<td>&quot; Peru</td>
<td>1,458</td>
<td>6,294</td>
</tr>
<tr>
<td>&quot; other parts</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Total: 26,830 £118,039
BORAX.  

(Borax, Fr.; Bovar, Germ.)  

Anhydrous Borax is composed of—

<table>
<thead>
<tr>
<th>Equivalent</th>
<th>Soda</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>872</td>
<td>390</td>
</tr>
<tr>
<td>2</td>
<td>744</td>
<td>158</td>
</tr>
<tr>
<td>5</td>
<td>387</td>
<td>79</td>
</tr>
</tbody>
</table>

Octahedral Borax—

<table>
<thead>
<tr>
<th>Equivalent</th>
<th>Soda</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>872</td>
<td>390</td>
</tr>
<tr>
<td>5</td>
<td>390</td>
<td>195</td>
</tr>
</tbody>
</table>

Prismatic Borax—

<table>
<thead>
<tr>
<th>Equivalent</th>
<th>Soda</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>872</td>
<td>390</td>
</tr>
<tr>
<td>10</td>
<td>125</td>
<td>625</td>
</tr>
</tbody>
</table>

Tincal was originally brought from a salt lake in Tibet; the borax was dug in masses from the edges and shallow parts of the lake; and in the course of a short time the holes thus made were again filled. The borax of soda has been found at Potosí, in Peru; and it has been discovered by Mr. T. Sterry Hunt, of the Geological Survey, in Canada, from whose report the following extract is made:

"In the township of Joly there occurs a very interesting spring on the banks of the Ruisseau MAGNUM, a branch of the Rivière Soué, about five miles from the mills of Methot at Saint Croix. The spring furnishes three or four gallons a minute of a water which is sulphurous to the taste and smell, and deposits a white matter along its channel, which exhibits the purple vegetation generally met with in sulphur springs. The temperature of this spring in the evening of one 7th of July was 46° F., the air being 52° F. The water is not strongly saline, but when concentrated is very alkaline and salt to the taste. It contains, besides chlorides, sulphates, and carbonates, a considerable proportion of borax acid, which is made evident by its power of reddening paper colored by turmeric, after being supersaturated with hydrochloric acid. The analysis of 1,000 parts of the water gave as follows:

Chloride of sodium — 0.3818  
Potassium — 0.0067  
Sulphate of soda — 0.0215  
Carbontre and borate of do. — 0.2501  
Lime — 0.0820  
magnesia — 0.007  
Silica — 0.0254  
Alumina — a trace  
Air — 0.7528

The amount of borax acid estimated was found to be equal to 0.0279."

Professor Bechi has analyzed a borax occurring as an incarnate at the Tuscan lagoons, which afforded borax acid 45.56, sods 19.25, and water 37.19. Lagonite is a mineral of an earthy yellow color, which appears to be borax acid and iron; while Lar- drelite, also from Tuscan, is a compound of borax acid and soda. See Dana, and "American Journal of Science."

BORING.  

The importance of boring, as a means of searching for coal and for water, renders it necessary that some special attention should be given to the subject in a work devoted to manufactures and mining.

Boring for water appears to have been in use from the earliest periods, in Egypt and in Asia. In many of the desert tracts there are remains of borings, which served, evidently, at one period, to supply the wants of extensive populations which once inhabited those now deserted regions. In the "Guide du Soudeur," by M. J. Degouasse, we find it stated, with reference to China, "There exists in the canton of Ou-Tong-Kiao many thousand wells in a space of ten leagues long by five broad. These wells cost a thousand and some hundred taels, (the tael being of the value of 62. 6d.,) and are from 1,500 to 1,800 feet deep, and about 6 inches in diameter. To bore these wells, the Chinese commence by placing in the earth a wooden tube of 3 or 4 inches diameter, surmounted by a stone edge, pierced by an orifice of 5 or 6 inches; in the tube a trepan is allowed to play, weighing 500 or 400 lbs. A man, mounted on a scaffold, swings a block, which raises the trepan 2 feet high, and lets it fall by its own weight. The trepan is secured to the swing-lever by a cord made of reeds, to which is attached a triangle of wood; a man
sits close to the cord, and at each rise of the swing seizes the triangle and gives it a half turn, so that the trepan may take in falling another direction. A change of workmen goes on day and night, and with this continuous labor they are sometimes three years in boring wells to the requisite depth."

Boring appears to have been practised in England during the last century, but to a very limited extent; it has, however, for a considerable period been employed in seeking for coal, and in the formation of wells.

The ordinary practice of boring is usually carried out, by first sinking a well of such a depth that the boring apparatus can be fixed in it; and thus a stage, raised from the surface of the ground, is dispensed with. A stout plank floor, well braced, together by planks nailed transversely and resting on putlocks, forms the stage. In the centre of the floor is a square hole, through which the boring-rods pass. The boring-rods are of many different forms. A few are represented in the following figure, (70.)

1, 2, 3 are an elevation, plan, and section of an auger; the tapped socket is for the purpose of allowing the rods to be screwed into it.

4, 5 are two views of a small auger, with a longitudinal slit, and no valve, which is used for boring through clay and loam. In very stiff clay the slit is generally made larger; in moist ground the slit is objectionable.

6, 7, 8 are different views of a shell. a a are valves opening upwards, to admit the material. These tools are used for boring through sand, or through ground which has been loosened by other tools.

9, 10, 11 show an S chisel, for cutting through rocks, flints, and the like.

Such are the principal tools employed. The boring-rods are turned round by the leverage of two handles moved by man, or, where the work is heavy, by horse, or, sometimes, even steam power is applied. Besides the circular motion of the tool, a vertical percussive action of the same is required in certain cases, such as rock or hard sand; indeed, always, where the position of the auger or chisel requires a fresh place to act upon during its revolution. This motion is most readily got by suspending the boring-rods to a windlass, through the intervention of a rope coiled two or three times round the latter, and adjusting it so that if the workman holds one end of the coil tight, suffi-
BORENG.

Client will be the friction to raise the rods on putting the windlass in motion. Should the end of the rope the workman holds now be slackened, the coil becomes loose, and the rods descend with a force equivalent to their weight and the distance through which they have fallen. A regular percussive action is thus gained by keeping the windlass continually in motion in one direction, the attendant workman alternately allowing the rods to be drawn up a certain distance, and then, by relaxing his hold, allowing them to fall. — Swindell, on Boring.

The following list of the prices of boring, in different localities, may prove useful:

In the North of England, the prices for boring, in the ordinary strata of the district or of that coal field, are as follows:

<table>
<thead>
<tr>
<th>Depth</th>
<th>s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 5 fathoms</td>
<td>5 6 per fathom.</td>
</tr>
<tr>
<td>Second 5</td>
<td>11 0</td>
</tr>
<tr>
<td>Third 5</td>
<td>16 6</td>
</tr>
<tr>
<td>Fourth 5</td>
<td>22 0</td>
</tr>
</tbody>
</table>

and so increasing 5s. 6d. per fathom on each succeeding depth of 5 fathoms. When any unusually hard strata are met with, the borer is paid by special arrangement, unless a binding contract has been previously made. It is sometimes usual for the borer to take all risk of hard strata, when the prices are as follows, the borer finding the tools:

<table>
<thead>
<tr>
<th>Depth</th>
<th>s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 5 fathoms</td>
<td>7 6 per fathom.</td>
</tr>
<tr>
<td>Second 5</td>
<td>15 0</td>
</tr>
<tr>
<td>Third 5</td>
<td>22 6</td>
</tr>
<tr>
<td>Fourth 5</td>
<td>30 0</td>
</tr>
</tbody>
</table>

and so increasing 7s. 6d. per fathom on each succeeding depth of 5 fathoms.

In the Midland Counties, where the strata are more inclined than in the north of England, the prices for ordinary strata are as follows:

<table>
<thead>
<tr>
<th>Depth</th>
<th>s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 20 yards</td>
<td>3 6 per yard.</td>
</tr>
<tr>
<td>Next 10</td>
<td>5 0</td>
</tr>
<tr>
<td>&quot; 10</td>
<td>6 6</td>
</tr>
<tr>
<td>&quot; 10</td>
<td>8 0</td>
</tr>
<tr>
<td>&quot; 10</td>
<td>9 6</td>
</tr>
</tbody>
</table>

and so advancing 1s. 6d. per yard upon each 10 yards.

In some localities, where the boring is still more favorable, the prices are as follows, —the bore hole being 2½ to 2¾ inches diameter:

<table>
<thead>
<tr>
<th>Depth</th>
<th>s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 20 yards</td>
<td>3 6 per yard.</td>
</tr>
<tr>
<td>Next 10</td>
<td>4 6</td>
</tr>
<tr>
<td>&quot; 10</td>
<td>5 6</td>
</tr>
<tr>
<td>&quot; 10</td>
<td>6 6</td>
</tr>
<tr>
<td>&quot; 10</td>
<td>7 6</td>
</tr>
</tbody>
</table>

In boring strata of unusual hardness, a special arrangement is made, as before stated, and the borer is allowed some payment for filling up and for removing tackling.

In Scotland the general prices for boring are as follows:

<table>
<thead>
<tr>
<th>Depth</th>
<th>s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 5 fathoms</td>
<td>5 0 per fathom</td>
</tr>
<tr>
<td>Second 5</td>
<td>10 0</td>
</tr>
<tr>
<td>Third 5</td>
<td>15 0</td>
</tr>
<tr>
<td>Fourth 5</td>
<td>20 0</td>
</tr>
</tbody>
</table>

and so advancing 5s. per fathom for each succeeding 5 fathoms.

In boring through very hard strata, the work is done either by shaft-work, or at the following rates, the bore hole being 2¾ inches diameter:

<table>
<thead>
<tr>
<th>Depth</th>
<th>s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 5 fathoms</td>
<td>10 0 per fathom.</td>
</tr>
<tr>
<td>Second 5</td>
<td>20 0</td>
</tr>
<tr>
<td>Third 5</td>
<td>30 0</td>
</tr>
</tbody>
</table>

The borer usually specifies to have his tackle laid down ready for erecting at the cost of the employer.

As the boring proceeds, it is often necessary to lower pipes into the hole made, to prevent the falling of fragments from the sides of the cylinder. There are many ingenious contrivances for effecting this, which need not be described in this place. See Fr. Coal, vol. i.
BORON. One of the non-metallic elements; it exists in nature in the form of boracic acid, and as borax, thidic, &c.

Hofmann is said to have obtained boron from borax in 1792; if so, his discovery appears to have been forgotten, since it was unknown, except hypothetically, to the more modern chemists until, in 1808, it was obtained by Gay-Lussae and Thénard, and by Davy in 1808, who decomposed boracic acid into boron and oxygen.

Boron is best obtained by preparing the double fluoride of boron and potassium, (3K₂B₃F₄) by saturating hydrofluoric acid with boracic acid, and then gradually adding fluoride of potassium. The difficulty soluble double compound thus produced is collected and dried at a temperature nearly approaching to redness. This compound is then powdered and introduced into an iron tube closed at one end, together with an equal weight of potassium, whereupon heat is applied sufficient to melt the latter, and the mixture of the two substances is effected by stirring with an iron wire. Upon the mass being exposed to a red heat, the potassium abimits the fluoride. The fluoride of potassium may afterwards be removed by heating the mass with a solution of chloride of ammonium, which converts the free potassa into chloride of potassium, and thus prevents the oxidation of the boron, which takes place in the presence of fixed alkali; the chloride of ammonium adhering to the boron may be afterwards removed by treatment with alcohol. Boron is a dark greenish-brown powder, tasteless, and inodorous; its chemical equivalent is 10.9; or, according to Laurent, 11.9.

BOTTLE MANUFACTURE. See Glass and Pottery.

BOULDERING STONE. A name given by the Sheffield cutlers to the smooth flint pebbles with which they smooth down the faces of buff and wooden wheels. As these stones are usually taken from gravel pits, the name is, no doubt, used in the same sense as that the geologist uses the word Boulders.

BOX WOOD. (Buis, Fr.; Buchsbaum, Germ.; Boxa sempervirens.) Two varieties of box wood are imported into this country. The European is brought from Leghorn, Portugal, &c.; and the Turkey box wood from Constantinople, Smyrna, and the Black Sea.

English box wood grows plentifully at Box Hill, in Surrey, and in Gloucestershire. The English box wood is used for common turnery, and is preferred by brass finishers for their lathe-chucks, as it is tougher than the foreign box, and bears rougher usage. It is of very slow growth, as in the space of 25 years it will only attain a diameter of 1½ to 2 inches.

—Holtzappel.

Box wood is used for making clarionets and flutes, carpenters' rules, and drawing scales.

As the wood is peculiarly free from gritty matter, its sawdust is used for cleaning jewellery. Box wood is exclusively employed by the wood engraver. See Engraving on Wood.

A similar wood was imported from America by the name of Tignawena, which was used for making ladies' fans; but we cannot learn that it is now employed.

BRASS. The table on the following page, for the compilation of which we are indebted to Mr. Robert Mallet, C. E., presents, in a very intelligible form, the chemical and physical conditions of the various kinds of brass:

Brass Colons, for staining glass, is prepared by exposing for several days thin plates of brass upon tiles in the beer, or annealing arch of the glass house, till they are oxidized into a black powder, aggregated in lumps. This being pulverized and sifted, is to be again well calcined for several days more, till no particles remain in the metallic state, when it will form a fine powder of a rusted-brown color. A third calcination must now be given with a carefully regulated heat, its quality being tested from time to time by fusion with some glass. If it makes the glass swell and intumesce, it is properly prepared; if not, it must be still further calcined. Such a powder communicates to glass greens of various tints, passing into turquoise.

When thin narrow strips of brass are stratified with sulphur in a crucible and calcined at a red heat, they become friable and may be reduced to powder. This being sifted and exposed upon tiles in a reverberatory furnace for 10 or 12 days, becomes fit for use, and is capable of imparting a chalcedony—red or yellow—tinge to glass by fusion, according to the mode and proportion of using it.

The glassmakers' red color may be prepared by exposing small plates of brass to a moderate heat in a reverberatory furnace till they are thoroughly calcined, when the substance becomes pulverulent, and assumes a red color. It is then ready for immediate use.

Mr. Holtzappel, in his "Mechanical Manipulation," has given some very important descriptions of alloys. From his long experience in manufacture, no one was more capable than Mr. Holtzappel to speak with authority on the alloys of copper and zinc. From his work the following particulars have been obtained:

The red color of copper slides into that of yellow brass at about 4 or 5 ounces of zinc to the pound of copper, and remains little altered into about 8 or 10 ounces; after this it becomes whiter, and when 32 ounces of zinc are added to 16 of copper, the mixture has the brilliant silvery color of speculum metal, but with a bluish tint.

These alloys—from about 8 to 16 ounces to the pound of copper—are extensively used.
<table>
<thead>
<tr>
<th>Chemical Constitution</th>
<th>Composition by Weight per Cent.</th>
<th>Atomic Weight II = 1</th>
<th>Specific Gravity</th>
<th>Fracture</th>
<th>Color of Fracture</th>
<th>Ultimate Cohesion per Square Inch</th>
<th>Inverse Order of Ductility</th>
<th>Order of Malleability at 60°</th>
<th>Inverse Order of Hardness, &amp;c.</th>
<th>Inverse Order of Fusibility, &amp;c.</th>
<th>Commercial Titles, characteristic Properties in Working, &amp;c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cu</td>
<td>100:00</td>
<td>0</td>
<td>31:6</td>
<td>E</td>
<td>Tile red</td>
<td>24:6</td>
<td>8</td>
<td>1</td>
<td>22</td>
<td>15</td>
<td>Copper.</td>
</tr>
<tr>
<td>2 Cu</td>
<td>90:72</td>
<td>9:28</td>
<td>34:82</td>
<td>CC</td>
<td>Reddish yellow, 1</td>
<td>21:1</td>
<td>6</td>
<td>13</td>
<td>21</td>
<td>14</td>
<td>Several of these are malleable at high temperatures.</td>
</tr>
<tr>
<td>3 Cu</td>
<td>89:80</td>
<td>10:20</td>
<td>31:6</td>
<td>FC</td>
<td>Ditto</td>
<td>11:5</td>
<td>4</td>
<td>11</td>
<td>20</td>
<td>13</td>
<td>Similar, &amp;c.</td>
</tr>
<tr>
<td>4 Cu</td>
<td>89:00</td>
<td>11:10</td>
<td>28:51</td>
<td>FC</td>
<td>Ditto</td>
<td>12:8</td>
<td>2</td>
<td>10</td>
<td>19</td>
<td>12</td>
<td>Bath metal.</td>
</tr>
<tr>
<td>6 Cu</td>
<td>85:40</td>
<td>14:60</td>
<td>22:19</td>
<td>FF</td>
<td>Yellowish red, 3</td>
<td>14:1</td>
<td>5</td>
<td>8</td>
<td>17</td>
<td>10</td>
<td>British brass.</td>
</tr>
<tr>
<td>7 Cu</td>
<td>83:02</td>
<td>16:98</td>
<td>19:02</td>
<td>FC</td>
<td>Ditto</td>
<td>13:7</td>
<td>11</td>
<td>2</td>
<td>16</td>
<td>9</td>
<td>Rolled sheet brass.</td>
</tr>
<tr>
<td>9 Cu</td>
<td>74:58</td>
<td>25:42</td>
<td>12:71</td>
<td>EC</td>
<td>Pale yellow</td>
<td>13:1</td>
<td>10</td>
<td>4</td>
<td>14</td>
<td>7</td>
<td>German brass.</td>
</tr>
<tr>
<td>10 Cu</td>
<td>71:47</td>
<td>28:57</td>
<td>22:6</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>German brass, watchmakers'.</td>
</tr>
<tr>
<td>11 Cu</td>
<td>68:18</td>
<td>33:82</td>
<td>95:5</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Very brittle</td>
</tr>
<tr>
<td>12 Cu</td>
<td>60:79</td>
<td>39:23</td>
<td>98:8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Ditto Too hard to file</td>
</tr>
<tr>
<td>13 Cu</td>
<td>49:47</td>
<td>50:53</td>
<td>63:9</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Ditto or turn; lustre</td>
</tr>
<tr>
<td>14 Cu</td>
<td>32:85</td>
<td>67:15</td>
<td>20:1</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Brittle nearly equal to</td>
</tr>
<tr>
<td>15 Cu</td>
<td>31:32</td>
<td>68:48</td>
<td>97:21</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Ditto spectrum metal.</td>
</tr>
<tr>
<td>16 Cu</td>
<td>30:37</td>
<td>69:70</td>
<td>98:1</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Very brittle</td>
</tr>
<tr>
<td>17 Cu</td>
<td>29:17</td>
<td>70:83</td>
<td>96:6</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Barely malleable.</td>
</tr>
<tr>
<td>18 Cu</td>
<td>28:12</td>
<td>71:88</td>
<td>98:8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Brittle.</td>
</tr>
<tr>
<td>19 Cu</td>
<td>27:10</td>
<td>72:90</td>
<td>91:1</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>White button metal.</td>
</tr>
<tr>
<td>20 Cu</td>
<td>26:24</td>
<td>73:76</td>
<td>95:6</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Brittle.</td>
</tr>
<tr>
<td>21 Cu</td>
<td>25:39</td>
<td>74:61</td>
<td>98:5</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Bristle.</td>
</tr>
<tr>
<td>22 Cu</td>
<td>24:50</td>
<td>75:50</td>
<td>128:5</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Brilke.</td>
</tr>
<tr>
<td>23 Cu</td>
<td>19:65</td>
<td>80:36</td>
<td>160:8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Brilke.</td>
</tr>
<tr>
<td>24 Cu</td>
<td>16:36</td>
<td>83:64</td>
<td>193:1</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Brilke.</td>
</tr>
<tr>
<td>25 Cu</td>
<td>0:00</td>
<td>100:00</td>
<td>23:5</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Brilke.</td>
</tr>
</tbody>
</table>

* E, signifies earthy; CC, coarse crystalline; FC, fine crystalline; FF, fine fibrous; C, conchoidal; V, vitreous; VC, vitreo-conchoidal; TC, tubular crystalline.
for dipping, a process adopted for giving a fine color to an enormous variety of furniture work. The alloys with zinc retain their malleability and ductility well unto about 8 or 10 ounces to the pound; after this the crystalline character slowly begins to prevail. The alloy of 2 zinc and 1 copper may be crumbled in a mortar when cold. In the following list, the quantity of zinc employed to 1 lb. of copper is given:

1 to 1½ oz. gilding metal for common jewellery.
3 to 4 oz. Bath metal, pinchbeck, Mannheim gold, Similor; and alloys bearing various names, resembling inferior jewellers' gold.
8 oz. Emerson's patent brass.
10½ oz. Muntz's metal, or 40 zinc and 60 copper. "Any proportion," says the patentee, "between the extremes, 50 zinc and 50 copper and 37 zinc and 63 copper, will roll and work well at a red heat."
16 oz. soft spelter solder, suitable for ordinary brass work.
16½ oz. Hamilton and Parker's patent mosaic gold.

Brass is extensively employed for the bearings of machinery. Several patents have been taken out for compositions varying but slightly. The following, for improvements in casting the bearings and brasses of machinery, appears important. Mr. W. Hewitson, of Leeds, directs, in his patent, that the proper mixture of alloy, copper, tin, and zinc, should be run into metal or "chill" moulds, in place of the ordinary mould. In large castings, it is found more especially that the metals do not mix intimately in cooling, or, rather, they arrange themselves into groups when cast in sand, and the bearings are found to wear out more quickly; but if the bearings are cast so that the alloy comes in contact with metal, the mixture is more intimate, and the bearings last longer than if cast in dry or green sand moulds.

Mr. Hewitson generally only applies these chill-metal surfaces of the moulds to those parts of a brass, or bearing, that are to receive the shaft or bear the axis of a machine. The chills are preferred of iron, perforated with holes (⅛ to ½ inch) for the passage of air or vapors; the surface should be thinly coated with loam, and heated to about 200°.

Fenton's patent metal consists of copper, spelter, and tin; it has less specific gravity than gun metal, and is described as being "of a more soapy nature," by which, consequently, the consumption of oil or grease is lessened.

Many of the patentees of bearing-metals assure us that the metals they now use differ very considerably from the statement in their specifications. Surely this requires a careful examination.

We exported of our brass manufactures, in 1856, 19,198 cwt., the declared real value of which was £121,296.

**BRASSING IRON.** Iron ornaments are covered with copper or brass by properly preparing the surface, so as to remove all organic matter, which would prevent adhesion, and then plunging them into melted brass. A thin coating is thus spread over the iron, and it admits of being polished or burnished. The electro-magnetic process is now employed for the purpose of precipitating brass on iron. This process was first mentioned in Shaw's "Metallurgy," in 1814, where he remarks, "In depositing copper upon iron, a solution of the cyanide or acetate of copper should be employed. The only value of these salts is, that a die or surface of iron may be immersed in their solutions without receiving injury by the corrosion consequent upon the deposition of a film of metal by chemical action." The following solutions are recommended by Dr. Woods, in the "Scientific American," for coating iron with copper, iron, or brass, by the electrolytic process:

To make a Solution of Copper or Zinc.—Dissolve 8 ounces (troy) cyanide of potassium and 3 ounces of cyanide of copper or zinc in 1 gallon of rain or distilled water. These solutions to be used at about 160° F. with a compound battery of from 3 to 12 cells.

To prepare a Solution of Brass.—Dissolve 1 lb. (troy) cyanide of potassium, 2 ounces of cyanide of copper, and 1 ounce of cyanide of zinc, in 1 gallon of rain or distilled water; then add 2 ounces of muriate of ammonia. This solution is to be used at 160° F. for smooth work, and from 90° to 120°, with a compound battery of from 3 to 12 cells. See Electro-Metallurgy.

**BRAZIL WOOD.** The *ibiripilana*, or Brazil wood, called, in Pernambuco, *pau da rainha, (Queen's wood,) on account of its being a Government monopoly, is now rare to be seen within many leagues of the coast, owing to the improvident manner in which it has been cut down by the Government agents, without any regard being paid to the size of the tree or its cultivation. It is not a lofty tree. At a short distance from the ground, innumerable branches spring forth and extend in every direction in a struggling, irregular, and unpleasing manner. The leaves are small and not luxuriant; the wood is very hard and heavy, takes a high polish, and splits in water: the only valuable portion of it is the heart, as the outward coat of wood has not any peculiarity. The name of this wood is derived from *brasas*, a glowing fire or coal; its botanical name is *Cesalpinia Brasileta*. The leaves are pinnated, the flower white and papilionaceous, growing in a pyramidal spike; one spe-
BREAD.

dies has flowers variegated with red. The branches are slender and full of small prickles. There are nine species. See Bell's "Geography."

The species Brasiletto, which is inferior to the crista, grows in great abundance in the West Indies. The demand for the Brasiletto, a few years ago, was so great, owing to its being a little cheaper than the crista, that nearly the whole trees in the British possessions were cut down and sent home, which Mr. Bell very justly terms imposition. It is not now so much used, and is consequently scarcer in the English market. The wood known in commerce as Pernambuco is most esteemed, and has the greatest quantity of coloring matter. It is hard, has a yellow color when newly cut, but turns red by exposure to the air. That kind termed Lima wood is the same in quality. Sapan wood grows in Japan, and in quality is next the two named above. It is not plentiful, but is much valued in the dyehouse for red of a certain tint; it gives a very clear and superior color. The quantity of ash that these two qualities of wood contain is worthy of remark. Lima wood, as imported, gives the average of 27 per cent, while Sapan wood gives 15 per cent.; in both, the prevailing earth is lime. The quantity of moisture in the wood averages about 10 per cent.; that in the ground wood in the market about 20 per cent.

Peach wood, or Nicaragua, and sometimes termed Santa Martha wood, is inferior to the other two named, but is much used in the dyehouse, and, for many shades of red, is preferred, although its coloring matter is not so great. It gives a bright dye. The means of testing the quality of these woods by the dyer is similar to that described for logwood, with the same recommendations and precautions.—Napier on Dyeing.

BREAD. One of the most important, if not altogether the most important, article of food, unquestionably, is bread; and although rye, barley, oats, and other cereals are sometimes used by the baker, wheat is the grain which is best fitted for the manufacture of that article, not only on account of the larger amount of gluten, or nitrogenous matter, which it contains, and than can be found in other edible grains, but also on account of the almost exact balance in which the non-nitrogenous and non-nitrogenous constituents exist in that cereal, and owing to which it is capable of ministering to all the requirements of the human frame, and of being assimilated at once and without effort by our organs, whence the name of "staff of life," which is often given to it, wheat being, like milk, a perfect food.

Although gluten is one of the most important constituents of wheat, the nutritive power of its flour, and its value as a bread-making material, should not be altogether considered as dependent upon the quantity of gluten it may contain, even though it be of the best quality. Doubtless a high percentage of this material is desirable, but there are other considerations which must be taken into account; for, in order to become available for making good bread, flour, in addition to being sound and genuine, must possess other qualities beyond containing merely a large amount of gluten. Thus, for example, the blé rouge glace d'Auvergne, which contains hardly 45 per cent. of starch, and as much as 56 per cent. of gluten, though admirably adapted for the manufacture of macaroni, vermicelli, semolina, and other pâtes d'Italie, is totally unfit for making good bread; the flour used for making best white loaves containing only from 10 to 15 per cent. of gluten, and from 60 to 70 per cent. of starch.

Bread is obtained by baking a dough, previously fermented either by an admixture of yeast or leaven, or it is artificially rendered spongy by causing an acid, curative or tartaric, to react upon carbonate or bicarbonate of soda, or of ammonia, mixed in the doughy mass; or, as in Dr. Dungliah's process, which will be described further on, by mixing the flour which has to be converted into dough, not with ordinary water, but with water strongly impregnated with carbonic acid.

The conversion of flour into bread includes two distinct operations—namely, the preparation of the dough, and the baking. The preparation of the dough, however, though reckoned as one, consists, in fact, of three operations—namely, hydrating, kneading, and fermenting.

When the baker intends to make a batch of bread, his first care is, in technical language, to stir a ferment. This is done, in London, by boiling a few potatoes, in the proportion of 5 lbs. or 6 lbs. of potatoes per sack of flour, (which is the quantity we shall assume it is desired to convert into bread,) peeling them, mashing and straining them through a colander, and adding thereto about three-quarters of a pailful of water, 2 or 3 lbs. of flour, and one quart of yeast. The water employed need not be warmed beforehand, for the heat of the potatoes is sufficient to impart a proper temperature (from 70° to 90° F.) to the liquid mass, which should be well stirred up with the hand into a smooth, thin, and homogeneous paste, and then left at rest.

In the course of an hour or two, the mass is seen to rise and fall, which swelling and heaving up is due to carbonic acid, generated by the fermentation induced in the mass, which may be thus left until wanted. In about three hours, this fermenting action will appear to be at an end, and when it has arrived at that stage, it is fit to be used. The ferment, however, may be left for six or seven hours and be still very good at the end of that time, but the common practice is to use it within four or five hours after its preparation.
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The next operation consists in "setting the sponge." This consists in stirring the ferment well, adding thereto about two gallons of lukewarm water, and as much flour as will make, with the ferment, a rather stiff dough. This constitutes "the sponge." It is kept in a warm situation, and in the course of about an hour, fermentation again begins to make its appearance, the mass becomes distended or is heaved up by the carbonic acid produced, the escape of which is impeded by the toughness of the mass. This carbonic acid is the result of the fermentation induced under the influence of water, by the action of the gluten upon the starch, a portion of which is converted thereby into sugar, and then into alcohol. A time, however, soon comes when the quantity of carbonic acid thus pent up becomes so great that it bursts through, and the sponge collapses or drops down. This is called the first sponge; but as the fermentation is still going on, the carbonic acid soon causes the sponge to rise again as before to nearly twice its volume, when the carbonic acid, bursting through the mass, causes it to fall a second time; and this constitutes what the bakers call the second sponge. The rising and falling might then go on for twenty-four hours; but as the albolic would pass into the aseptic fermentation soon after the second rising, the baker always interferes after the second, and very frequently after the first sponge. The bread made from the first sponge is generally sweeter; but, unless the best flour is used, and even then, the loaf that is made from it is smaller in size and more compact than that which is made with the second sponge. In hot weather, however, as there would be much danger of the bread turning sour, if the sponge were allowed to "take a second fall," the first sponge is frequently repeated. The second sponge consists in breaking the sponge, which is done by adding to it the necessary quantity of water and of salt,—the quantity of the latter substance varying from $\frac{1}{2}$ to $\frac{3}{4}$ lb. per bushel of flour; that is, from $\frac{1}{2}$ to $\frac{3}{8}$ lb. per sack of flour, (new flour, or flour of inferior quality, always requires, at the very least, $\frac{3}{8}$ lb. per sack, to bind it, that is to say, to render the dough sufficiently firm to support itself while fermenting.) Salt acts, to a great extent, like alum, though not so powerfully. As to the quantity of water to be used, it depends also a great deal on the quality of the flour, the best quality absorbing most; though, as we shall have occasion to remark, the baker too often contrives to force and keep into bread made from inferior flour, by a process called under-baking, the same amount of water as is normally taken up by that of the best quality. Generally speaking, and with flour of good average quality, the amount of water is such that the diluted sponge forms about 14 gallons of liquid. The whole mass is then torn to pieces by the hand, so as to break any lumps that there may be, and mix it up thoroughly with the water. This being done, the rest of the sack of flour is gradually added and kneaded into a dough of the proper consistency. This kneading of the dough may be said to be one of the most important processes of the manufacture, since it not only produces a more complete hydration of the flour, but, by imprisoning a certain quantity of air within the dough, and forcibly bringing into closer contact the molecules of the yeast or leaven with the sugar of the flour, and also with a portion of the starch, the fermentation or rising of the whole mass, on which the sponginess of the loaf and its digestibility subsequently depend, is secured. When, by forcing the hand into the dough, the baker sees that, on withdrawing it, none of the dough adheres to it, he knows that the kneading is completed. The dough is then allowed to remain in the trough for about an hour and a half or two hours, if Brewers' or German yeast, has been employed in making the sponge; if, on the contrary, patent yeast or Hop yeast have been used, three or even four hours may be required for the dough to rise up, or, as in technical language, to give proof. When the dough is sufficiently "proofed," it is weighed off into lumps, shaped into the proper forms, of 4 lbs. 4 oz. each, and exposed for about one hour in an oven to a temperature of about 570° F., the heat gradually falling to 430 or 420° F. The yield after baking is 94 quarts (not 4 lb.) loaves, or from 90 to 92 really 4 lb. loaves, as large again as they were when put into the oven in the shape of dough.

The manner in which yeast acts upon the flour is, as yet, an unsolved mystery, or, at any rate an, as yet, unsatisfactorily explained action; for the term "catalysis," which has sometimes been applied to it, explains absolutely nothing.

A yeast, or fermenting material, may be prepared in various ways; but only three kinds of yeast are used by bakers: namely, brewers' yeast, or barn,—German yeast, and patent, or hop yeast.

The most active of these ferments is the first, or brewers' yeast; it is, as is well known, a frothy, thickish material, of a brownish or drab color, which, when recent, is in a state of slight effervescence, exhalas a sour characteristic odor, and has an acid reaction.

When viewed through the microscope, it is seen to consist of small globules of various size, generally egg-shaped. They were first described by M. Desmayères.

The best, and in fact the only brewers' yeast used in bread-making, is that from the ale breweries; porter yeast is unavailable for the purpose, because it imparts to the bread a disagreeable bitter taste.

German yeast is very extensively used by bakers. It is a pasty but easily crumbled mass, of an agreeable fruity odor, and of a dingy white color. German yeast will remain
good for a few weeks, if kept in a cool place. When in good condition, it is an excellent article; but samples of it are occasionally seized on bakers' premises, of a darker color, viscid, and emitting an offensive cheesy odor: such German yeast, being in a putrefied state, is, of course, objectionable.

The so-called "potent yeast" is the cheapest and at the same time the weakest of these ferment[s]; very good bread, however, is made with it, and it is most extensively used by bakers. It is made either with or without hops: when with hops, it is called hop yeast, and is nothing more than a decoction of hops to which malt is added while in a scalding hot state; when the liquor has fallen to a blood heat, a certain quantity of brewers' or German yeast is thoroughly mixed with it, and the whole is left at rest. The use of the hops is intended to diminish the tendency of this solution to become acid.

Potato yeast is a kind of "potent yeast." In general use.

The theory of panification is not difficult of comprehension. "The flour," says Dr. Ure, "owes this valuable quality to the gluten, which it contains in greater abundance than any of the other cereals, (kinds of corn.) This substance does not constitute, as has been heretofore imagined, the membranes of the tissue of the perisperm of the wheat; but is inclosed in cells of that tissue under the epidermic coats, even to the centre of the grain. In this respect the gluten lies in a situation analogous to that of the starch, and of most of the immediate principles of the vegetables. The other immediate principles which play a part in panification are particularly the starch and the sugar; and they all operate as follows: -

"The diffusion of the flour through the water hydrates the starch, and dissolves the sugar, the albumen, and some other soluble matters. The kneading of the dough, by completing these reactions through a more intimate union, favors also the fermentation of the sugar, by bringing its particles into close contact with those of the yeast or yeast; and the drawing out and laminating the dough softens and stratifies it, introducing at the same time oxygen to aid the fermentation. The dough, when distributed and formed into loaves, is kept some time in a gentle warmth, in the folds of the cloth, pans, &c., a circumstance propitious to the development of their volume by fermentation. The dimensions of all the lumps of dough now gradually enlarge, from the disengagement of carbonic acid in the decomposition of the sugar, which gas is imprisoned by the glutinous paste. Were these phenomena to continue too long, the dough would become too vesicular; they must, therefore, be stopped at the proper point of sponginess, by placing the loaf lumps in the oven. Though this causes a sudden expansion of the enclosed gaseous globules, it puts an end to the fermentation, and to their growth; as also evaporates a portion of the water.

"The fermentation of a small dose of sugar is, therefore, essential to true bread-making; but the quantity actually fermented is so small as to be almost inappreciable. It seems probable that in well-made dough the whole carbonic acid that is generated remains in it, amounting to one-half the volume of the loaf itself at its baking temperature, or 212° F. It thence results that less than one-hundredth part of the weight of the flour is all the sugar requisite to produce well-raised bread.

"Although the rising of the dough is determined by the carbonic acid resulting from the decomposition of the sugar, produced by the reaction of the gluten on hydrated or moist flour, considering that the quantity of sugar necessary to produce fermentation does not amount, probably, to more than one-hundredth part of the weight of the flour employed, and perhaps to even considerably less than that,—the saving and economy which is said to accrue to the consumer from the use of unfermented bread (which is bread in which the action of yeast is replaced by an artificial evolution of carbonic acid, by decomposing bicarbonate of soda with muriatic acid, as we said before) is therefore much below what it has been estimated (25 per cent.!) by some writers; and it is certainly very far from compensating for the various and serious drawbacks which are peculiar to that kind of bread, one of which—and it is not the least—is its indigestibility, notwithstanding all that may have been said to the contrary.

"In a pamphlet entitled, 'Instructions for making Unfermented Bread, by a Physician,' published in 1846, the formula recommended for bread made of wheat meal is as follows:

| Wheat meal     | 3 lbs. avoirdupois |
| Bicarbonate of soda | 4½ drachms troy. |
| Hydrochloric acid     | 5 fluid drachms and 25 minims, or drops. |
| Water                | 30 fluid ounces. |
| Salt                 | ¾ of an ounce Troy. |

"Bread made in this manner," says the author, "contains nothing but flour, common salt, and water. It has an agreeable, natural taste, keeps much longer than common bread, is much more digestible, and much less disposed to turn acid," &c.

Liebig, in his "Letters on Chemistry," very judiciously remarks, "that the intimate mixture of the saliva with the bread, whilst masticating it, is a condition which is favorable to the rapid digestion of the starch; wherefore the porous state of the flour in fermented bread accelerates its digestion."

Now, it is a fact, which can readily be ascertained by any one, that unfermented bread
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is permeated by fluids with difficulty. It will not absorb water, hence its heavy and clammy feel; nor saliva, hence its indigestibility; nor milk, nor butter. Unfermented bread will neither make soup, nor tost, nor polish. When a slice of ordinary bread is held before a bright fire, a portion of the moisture of the bread, as the latter becomes scorched, is converted into steam, which penetrates the interior of the mass, and imparts to it the sponginess so well known in a toast properly made; but if a piece of unfermented bread be treated in the same manner, the steam produced by the moisture, not being able to penetrate the unabsorbed mass, evaporates, and the result is an uninviting slice, toasted, but hard inside and out, and into which butter penetrates about to the same extent as it would a wooden slab of the same dimensions.

"Fermentation," says Liebig, "is not only the best and simplest, but likewise the most economical way of imparting porosity to bread; and besides, chemists, generally speaking, should never recommend the use of chemicals for culinary preparations, for chemicals are seldom met with in commerce in a state of purity. Thus, for example, the muriatic acid which it has been proposed to mix with carbonate of soda in bread is always very impure, and very often contains arsenic. Chemists never employ such an acid in operations which are certainly less important than the one just mentioned, without having first purified it."

In order to remove this ground of objection, tartaric acid has been recommended instead of muriatic acid for the purpose of decomposing the carbonate of soda; but in that way another unsafe compound is introduced, since the result of the reaction is tartrate of soda, a diuretic and, consequently very objectionable salt, for it is impossible to say what mischief the continuous ingestion of such a substance may eventually produce; and whatever may be the divergence of opinion,—if there be such a divergence, —as to whether or not the constant use of an aperient, however mild, may be detrimental to health, it surely must be admitted that, at any rate, it is better to be safe from suspicion of such materials; and that, at any rate, if depressing their use be an error, it is an error on the safe side;—after all, a lardhouse is not a chemical laboratory.

Before leaving this question of unfermented bread, we must not omit to speak of a remarkable process invented by Dr. Dauglish, and which has lately excited some attention. Without discussing the value of the idea which is said to have led Dr. Dauglish to invent the process in question, we shall simply describe Dr. Dauglish's method of making bread, and give his own version of its benefits:

"Taking advantage of the well-known capacity of water for absorbing carbonic acid, whatever its density, in quantities equal to its own bulk, I first prepare the water which is to be used in forming the dough, by placing it in a strong vessel capable of bearing a high pressure, and forcing carbonic acid into it to the extent of say ten or twelve atmospheres, (about 150 to 180 lbs. per square inch;) "this the water absorbs without any appreciable increase in its bulk. The water so prepared will of course retain the carbonic acid in solution so long as it is retained in a close vessel under the same pressure. I therefore place the flour and salt, of which the dough is to be formed, also in a close vessel capable of bearing a high pressure. Within this vessel, which is of a spherical form, a simply-constructed kneading apparatus is fitted, worked from without through a closely-packed stuffing box. Into this vessel I force an equal pressure to that which is maintained in the airtight water-vessel; and then, by means of a pipe connecting the two vessels, I draw the water into the flour, and set the kneading apparatus to work at the same time. By this arrangement the water acts simply as limpid water among the flour, the flour and water are mixed and kneaded together into paste, and to such an extent as shall give it the necessary tenacity. After this is accomplished the pressure is released, the gas escapes from the water, and in doing so raises the dough in the most beautiful and expeditious manner. It will be quite unnecessary for me to point out how perfect must be the mechanical structure that results from this method of raising dough. In the first place, the mixing and kneading of the flour and water together, before any volatilizable property is imparted to the mass, render the most complete incorporation of the flour and water into a mass of very easy accomplishment; and this being secured, it is evident that the gas which forms the vesicle, or sponge, when it is released, must be dispersed through the mass in a manner which no other method—fermentation not excepted—could accomplish. But besides the advantages of kneading the dough before the vesicle is formed, in the manner above mentioned, there is another, and perhaps a more important one, from what it is likely to effect by giving scope to the introduction of new materials into bread-making,—and that is, I find that powerful machine-kneading, continued for several minutes, has the effect of imparting to the dough tenacity or toughness. In Messrs. Carr and Co.'s machine, at Carlisle, we have kneaded some wheaten dough for half an hour, and the result has been that the dough has been so tough that it resembled birdlime, and it was with difficulty pulled to pieces with the hand. Other materials, such as rye, barley, &c., are affected in the same manner. So that by thus kneading, I am able to blend the flour with the water, and make it to cohere like bread, from their wanting that quality in their gluten which is capable of holding or retaining, the same degree of lightness which no other method is capable of effecting. And I am sanguine of
being able to make from rye, barley, oatmeal, and other wholesome and nutritious substances, bread as light and sweet as the finest wheaten bread. One reason why my process makes a bread so different from all other processes where fermentation is not followed, is, that I am enabled to knead the bread to any extent without spoiling its peculiar property; whilst all other unfermented breads are merely mixed, not kneaded. The property thus imparted to my bread by kneading, renders it less dependent on being placed immediately in the oven. It certainly cannot gain by being allowed to stand after the dough is formed, but it bears well the necessary standing and waiting required for preparing the loaves for baking.

"There is one point which requires care in my process, and that is, the baking,—as the dough is excessively cold; first, because cold water is used in the process; and next, because of its sudden expansion on rising. It is thus placed in the oven some 40° Fahr. in temperature lower than the ordinary fermented bread. This, together with its slow springing until it reaches the boiling point, renders it essential that the top crust shall not be formed until the very last moment. Thus, I have been obliged to have ovens constructed which are heated through the bottom, and are furnished with the means of regulating the heat of the top, so that the bread is cooked through the bottom; and, just at last, the top heat is put on and the top crust formed.

"With regard to the gain effected by saving the loss by fermentation, I may state what must be evident, that the weight of the dough is always exactly the sum of the weight of flour, water, and salt put into the mixing vessel; and that, in all our experiments at Carlisle, we invariably made 118 loaves from the same weight of flour which by fermentation made only 105 and 106. Our advantage in gain over fermentation can only be equal to the loss by fermentation. As there has been considerable difference of opinion among men of science with respect to the amount of this loss,—some stating it to be as high as 1 1/2 per cent. and others so low as 1 per cent,—I will here say a few words on the subject. Those who have stated the loss to be as high as 1 1/2 per cent. have, in support of their position, pointed to the extra yield from the same flour of bread when made by non-fermentation, compared with that made by fermentation. Whilst those who have opposed this assertion, and stated the loss to be but 1 per cent. or little more, have declared the gain in weight to be simply a gain of extra water, and have based their calculations of loss on the destruction of material caused by the generation of the necessary quantity of carbonic acid to render the bread light. Starting then with the assumption that light bread contains in bulk half solid matter and half airiform, they have calculated that this quantity of airiform matter is obtained by a destruction of but one per cent. of solid material. In this calculation the loss of carbonic acid, by its escape through the mass of dough during the process of fermentation and manufacture, does not appear to have been taken into account. All who have been in any way practically connected with bakeries, well know how large this loss is, and how important it is that it should be taken into account, that our calculations may be correct.

"One of the strongest proofs that the escape of gas through ordinary soft bread dough is very large, arises from the fact that when biscuit dough, in which there is a mixture of fatty matter, is prepared by my process, about half the quantity of gas only is needed to obtain an equal amount of lightness with dough that is made of flour and water only; the fatty matter acting to prevent the escape of gas from the dough. Other matters will operate in a similar manner—boiled flour, for instance, added in small quantities. But the assumption that light bread is only half airiform matter is altogether erroneous. Never before has there been so complete a method of testing what proportion the airiform bears to the solid in light bread as that which my process affords. The mixing vessel at Messrs. Carr and Co.'s works, Carlisle, has an internal capacity of 10 bushels. When 24 bushels of flour are put into this vessel, and formed into spongy bread dough, by my process, it is quite full. And when flour is mixed with water into paste, the paste measures rather less than half the bulk of the original dry flour. This will therefore represent about 18 bushels of solid matter expanded into 10 bushels of spongy dough, showing in the dough nearly 5 parts airiform to 1 solid; and in all instances, if the baking of this dough has not been accomplished so as to secure the loaves to spring to at least double their size in the oven, they have always come out heavy bread when compared with the ordinary fermented loaves. This gives the relative proportion of airiform to solid in light bread at least as 10 to 1, and at once raises the loss by fermentation from 1 to 10 per cent., without taking into account the loss of gas by its passage through the mass of dough.

"Of the quality and properties of the bread manufactured by my process, there will shortly be ample means of judging. I may be allowed, however, here to state, that will be evident to all, that the absence of every thing but flour, water, and salt, must render it absolutely pure;—that its sweetness cannot be equalled except by bread to which sweet materials are superadded;—that, unlike all other unfermented bread, It makes excellent toast; and, on account of its high absorbent power, It makes the most delicious sop puddings, &c., and also excellent poultries. Sop pudding and poultries made from this bread,
however, differ somewhat from those made from fermented bread, in being somewhat richer or more glutinous. This arises from the fact of the gluten not having been changed, or rendered soluble, in the manner caused by fermentation; but that this is a good quality rather than a bad one, is evident from the fact, that the richer and purer fermented bread is, the more glutinous are the so-called, made from it; and the poorer and more adulterated with alum it is, the freer the sop, &c., are of this quality."

Such, then, is Dr. Dauglish's plan, and it is impossible to deny that it possesses great ingenuity. From the fact that, in all his experiments at Carlisle, Dr. Dauglish invariably made 112 loaves from the same weight of flour which, by fermentation, made only 105 or 106, to argue that the gain over fermentation can only be equal to the loss by fermentation, is to draw a somewhat hasty conclusion; for the gain may be, and is probably due, not to the preservation in the bread of what is generally lost by fermentation, but simply to a retention of water.

It is of course certain that the production of the porosity required in bread produced by the carbolic acid and alcohol evolved by fermentation, entails a certain portion of the valuable constituents of the flour, but the amount of that loss should not be estimated, I think, from the proportions which the aeriform bear to the solid matter of the loaf after it is baked.

In effect, the fermentation induced in bread differs from that produced at the distillery, inasmuch as, instead of the fermenting material being sheltered from the air by an atmosphere of carbolic acid, the dough is on the contrary thoroughly permeated by, and retains a considerable quantity of atmospheric air introduced into it by the kneading process, and owing to the presence of which, in fact, the nectous fermentation is carried on to a certain extent, within the dough, simultaneously with the alcoholic fermentations, so that even the 10 parts of aeriform matter to 1 of solid matter in a quartern loaf, are not altogether carbolic acid resulting from the fermentation, but are carbolic acid from that source mixed with the atmospheric air with which the dough is permeated. On the other hand, the aeriform matter thus imprisoned in the dough, expands to at least twice its volume when exposed to the temperature of the oven, and accordingly the bread after baking becomes as bulky again as the dough from which it was made, and this doubling of the volume being due to the expansion of the gases, and not to the fermentation, bears no proportion whatever to the amount of the sugar of the flour employed in the production of the alcohol and carbolic acid evolved. Moreover, as a quartern loaf, for example, purposes about 9 inches by 6½ inches by 5 inches, making a total of about 292 cubic inches, if we take nine-tenths of that to be aeriform matter, we have 262½ inches as the aeriform cubic contents of the quartern loaf.

It is ascertained beyond doubt by numerous experiments, that genuine, properly manufactured new bread contains, on an average, 42½ per cent. of water, and 57½ of flour, and consequently a quartern loaf weighing really four pounds, would consist of 11,900 grains of water and 16,000 grains of solid matter, 422½ grains of which are salt and inorganic matter; the rest, 15677½ grains, being starch and gluten. Now a quartern loaf measuring about 9 x 6½ x 5 inches, gives a total of 292 cubic inches. Assuming, with Dr. Dauglish, nine-tenths of that to be aeriform matter, we have 262½ inches as the aeriform cubic contents of a quartern loaf, but as the gases expanded in the dough to double their volume during its being baked into a loaf, we must divide by 2 the 262½ inches above alluded to, which gives 131¼ as the number of cubic inches of aeriform matter contained in the dough before it went into the oven. Again, assuming with Dr. Dauglish that these 131¼ cubic inches consist altogether of carbolic acid resulting from the fermentation of the flour, they would represent in weight only 62 grains of that gas, and as 1 equivalent = 198 of sugar produces 4 equivalents = 88 of carbolic acid, it follows that, at most, about 140 grains of sugar or solid matter out of the 15677½ of flour in the quartern loaf would have disappeared, which loss is less than 1 per cent., from which, however, it is necessary to make a considerable reduction, since a large quantity of air is mixed with that carbolic acid, and expanded with it in the oven. Unless, therefore, it can be satisfactorily proved that the unfermented bread manufactured by Dr. Dauglish's process is more nutritious, weight for weight, or more digestible, or possesses qualities which fermented bread has not, or is sold at a reduced price proportionate to the quantity of water thus locked up and passed off for bread, the benefits and advantages will be all on the manufacturer's side, but the purchasers of the unfermented bread will make but a poor bargain of it.

Of all the operations connected with the manufacture of bread, the most laborious, and that which calls most loudly for reform, is that of kneading. The process is usually carried on in some dark corner of a cellar, where the temperature is seldom less than 60°, and frequently more; by a man, stripped naked down to the waist, and painfully engaged in exerting his fingers from a clayey mass into which he furiously plunges alternately his clenched fists, heavily breathing as he, struggling, repeatedly lifts up the bulky and tena-
ious mass in his powerful arms, and with effort flings it down again with a groan fetched from the innermost recesses of his chest, and which almost sounds like an imprecation.

We know, on very good and unexceptionable authority, that a certain large bakery on the borders of a canal, actually pumped the water necessary for making the dough directly and at once from the canal, and this from a point exactly contiguous to the discharges of the cesspool of that bakery! And let us not imagine that this is a solitary instance of horrible filth. The following memorandum, recorded by Dr. Wm. A. Guy, in his admirable lecture on "The Evils of Night-work and Long Hours of Labor," delivered on Thursday, July 6, 1848, at the Mechanics' Institution, Southampton Buildings, will serve to illustrate the condition of the bakehouses:

1. Underground, two ovens, no daylight, no ventilation, very hot and sulphurous.
2. Underground, no daylight, two ovens, very hot and sulphurous, low ceiling, no ventilation but what comes from the doors. Very large business.
3. Underground, no daylight, often flooded, very bad smells, overrun with rats, no ventilation.

After mentioning several other establishments in the same, or even in a worse condition, than those just enumerated, Dr. Guy adds:

"The statements comprised in the foregoing memoranda are in conformity with my own observations. Many of the basements in which the business of baking is carried on are certainly in a state to require the assistance of the Commissioners of Sewers, and to invite the attention of the promoters of sanitary reform."

If we reflect that bread, like all porous substances, readily absorbs the air that surrounds it, and that, even under the best conditions, it should never, on that account, be kept in confined places, what must be the state of the bread manufactured in such a villainous manner, and with a slovenliness greater than it is possible for our imagination to conceive? What can prove better the necessity of Government supervision than such a fact? The heart sickens at the revolting thought, but, after all, there is really but little difference between the particular case of the bakery on the border of a canal above alluded to, and the mode of kneading generally pursued, and to which we daily submit.

In the sitting of the Institute of France, on the 23d of January, 1850, the late M. Arago presented and recommended to the Académie the kneading and baking apparatus of M. Rolland, then a humble baker of the 12th Arrondissement, which, it would appear, fulfils all the conditions of perfect kneading and baking.

"The kneading machine (petrin mécanique) of M. Rolland," says Arago, "is extremely simple, and can be easily worked, when under a full charge, by a young man from 15 to 20 years old; the necessity for horse labor or steam power may thus be eluded. The machine (figs. 71 to 74) consists of a horizontal axis traversing a trough containing all the dough requisite for one baking batch, and upon which axis a system of curvilinear blades, alternately long and short, are placed in such a manner that, while revolving, they describe two quarters of cylindrical surfaces with contrary curves, so that the convexity of one of these surfaces, and the concavity of the other, is turned towards the bottom of the trough. The axis has a fly-wheel, and is set in motion by two small cog-wheels connected with the handle, as represented in the following figures:"
The action of the kneading machine is both easy and efficacious. In 20, and, if necessary, in 15, or even 10 minutes, a sack of flour may be converted into a perfectly homogeneous and aerated dough, without either lumps or clods, and altogether superior to any dough that could be obtained by manual kneading. The time required in kneading varies according to the greater or less density of dough required; and the quantity of dough manufactured in that space of time varies, of course, also with the dimensions of the kneading-trough; for instance, in the trough provided with 16 blades, one sack and a half of flour can be kneaded at once; in that of 14 blades, one sack, and in that of 12 blades, two-thirds of a sack.

M. Rolland gives the following instructions for the use of the machine, in order to impart to the dough the qualities produced by the operations known in France under the names of frasage, contrefrasage, and soufflage, which we shall presently describe, and to which the bread manufactured in that country mainly owes, in the words of Dr. Ure, "a flavor, color, and texture, never yet equalled in London."

The necessary quantity of leaven or yeast is first diluted with the proper quantity of water, as described before; and in order to effect the mixture, the crank should be made to perform 50 revolutions alternately from right to left. — Frasage is the first mixture of the flour with the water. The flour is simply poured into the kneading-trough, or, better still, when convenience permits it, it is let down from a room above through a linen hose, which may be shut by folding it up at the extremity.

Three-fourths only of the flour should at first be put into the trough; the first revolutions of the kneader should be rather rapid, but during the remainder of the operation the turning should be at the rate of about two or three revolutions a minute, according to the density of the dough to be prepared. The dough thereby having time to be well drawn out between the blades, and to drop to the bottom of the trough. From 24 to 36 revolutions of the crank will generally be sufficient; but in order to obtain the dough in the condition which the frasage would give it in the usual way, it will be necessary to make about 250 revolutions of the crank alternately from right to left, about the same number of turns.

Contrefrasage is the completion of the process of mixing; and, in order to perform that operation, the last fourth part of the flour must now be added, the crank turned 150 revolutions, to wit: 75 turns rather slowly, alternately from right to left, and the remainder at the rate of speed above mentioned.

The operation of soufflage consists in introducing and retaining air in the paste. To effect this, the kneader should be made to perform, during nearly the whole time occupied in the operation, an almost continual motion backwards and forwards, by which means the dough is shifted from place to place; five revolutions being made to the right, and five to the left, alternately, taking care to accelerate the speed a little at the moment of reversing the direction of the revolving blades.

All these operations are accomplished in twenty or twenty-five minutes.

Of course, the reader should not imagine that these numbers must be strictly followed; they are given merely as a guide indicative of the modus operandi.

The kneading being completed, the dough is left to rest for some time, and then divided into lumps, of a proper weight, for each loaf. The workman takes one of these lumps in each hand, rolls them out, dusts them over with a little flour, and puts each of them separate in its panetton; he proceeds with the rest of the dough in the same manner, and
leaves all the lumps to swell, which, if the flour have been of good quality, will take place at a uniform rate. They are then fit for baking, which operation will be described presently.

The Hot-water Oven Biscuit-baking Company possesses also a good machine with which 1 cwt. of biscuit dough, or 2 cwt. of bread dough, can be perfectly kneaded in 10 minutes. The machine is an American invention, and of extraordinary simplicity, for it is in reality nothing more than a large corkscrew, working in a cylinder, by means of which the dough is triturated, squeezed, pressed, torn, hacked, and finally agglomerated as it is pushed along. The dough, as it issues from that machine, can at once be shaped into leaves of suitable size and dimensions. A machine capable of doing the amount of work alluded to does not come to more than from £6 to £7; the other forms of kneading machines are likewise inexpensive, so that, in addition to the economy of time which they realize, there does not seem to be any excuse for retaining the abomination of manual kneading.

Among superior and very desirable apparatus for bread-making, there are at any rate three which fulfil the desiderata above alluded to, in the most complete and economical manner. One of them is M. Mouchot's autothermal bakery; the second is A. M. Perkins' hot-water oven; the third is Rolland's hot-air oven, with revolving floors: all three are excellent.

Perkins' hot-water oven is an adaptation of that distinguished engineers' stove, which, as is well known, is a mode of heating by means of pipes full of water, and hermetically closed; but with a sufficient space for the expansion of the water in the pipes. As a means of warming buildings, the invention has already produced the very beneficial effects which have gained for it an extensive patronage. There is no doubt but that this novel application entitles the inventor to the warmest thanks of the public. The following figure (75) represents one of these ovens. \( A \), stove; \( b \), collar of iron pipe placed in the stove; \( c, c \), flowpipe; \( d \), plate of water; \( e \), oven charged with leaves; \( f \), pipes; \( g, g \), return hot-water pipe; \( h, h \), door of the oven; \( i, i \), flue for the escape of the vapors in the oven; \( j, j \), rigid bar of iron supporting the regulating box; \( k, k \), regulating box containing three small levers; \( l, l \), nut adjusted so that if temperature of the hot-water pipe is increased beyond the adjusted point, its elongation causes the nut to bear upon the levers in the box, \( m, m \), which levers, lifting the straight rod \( n, n \), shut the damper \( x, x \) of the stove; \( n \) is an index indicating the temperature of the hot-water pipes.

The oven is first built in the ordinary manner of sound brickwork, made very thick in order to retain the heat. Then the top and bottom of the internal surfaces are lined with wrought-iron pipes of one inch external diameter, and five-eighths of an inch internal diameter, and their surface amounts, in the aggregate, to the whole surface of the oven. These pipes are then connected to a coil in a furnace outside the oven. The coil having such a relative proportion of surface to that which is in the oven, that the pipes may be raised to a temperature of 550° F., and no more. This fixed and uniform temperature is maintained by a self-regulating adjustment peculiar to this furnace, which works with great precision, and which cannot get out of order, since it depends upon the expansion of the upper ascending pipe close to the furnace acting upon three levers connected with the damper which regulates the draught. The moveable nut at the bottom of that expanding pipe being adjusted to the requisite temperature, that precise temperature is uniformly retained. The
smallest fluctuation in the heat of the water which circulates in the pipes instantly sets the levers in motion, and the expansion of one-thirty-sixth part of an inch is sufficient to close the damper.

It will be observed, that if the pipe be heated to 550° F., the brickwork will soon attain the same temperature, or nearly so; and accordingly the oven will thus possess double the amount of the heating surface of ordinary ovens applicable to baking. The baking temperature of the oven is from 420° to 450° F., which is ascertained by a thermometer with which the oven is provided.

With respect to Rolland's oven, Messieurs Boussingault, Payen, and Poncelet, in their report to the Institute of France; Gaultier de Glaubry, in a report made in the name of the Committee of Chemical Arts to the Société d'Encouragement; and the late M. Arago, represented that oven as successfully meeting all the conditions of salubrity, cleanliness, and hygiene. Wood, coal, and ashes, are likewise banished from it, and neither smoke nor the heated air of the furnace can find access to it. As in Perkins', the furnace is placed at a distance from the mouth of the oven, but, instead of conveying the heat by pipes, as in the hot-water oven, it is the smoke and hot air of the furnace which, circulating through fan-shaped flues, ramifying under the floor, and spreading over the roof of the oven, impart to it the requisite temperature. The floor of the oven, on which the loaves are deposited, consists of glazed tiles, and it can thus be kept perfectly clean. The distinctive character of M. Rolland's oven, however, is that the glazed tiles just spoken of rest upon a revolving platform, which the workman gradually, or from time to time, moves round by means of a small handle, and without effort.

Figures 76 to 85 represent the construction and appearance of M. Rolland's oven on a reduced scale.

76. Front elevation.
77. Vertical section through the axis of the fire-grate.
78. Ditto, ditto.
79. Elevation of one of the vertical flues.
80. Suspension of the floors.

81. Plan of the first floor.
82. Plan of the sole.
83. Plan of the second floor.
84. Plan of the fire-grate and flues.
85. Plan of the portion under ground.

When the oven has to be changed, the workman deposits the first loaves, by means of a short peel, upon that part of the revolving platform which lies before the mouth of the oven, and when that portion is filled, he gives a turn with the handle, and proceeds to put the loaves in the fresh space thus presented before him, and so on, until the whole is fitted up. The door is then closed through an opening covered with glass, and reserved in the wall of the oven, which is lighted up with a jet of gas, or by opening the door from time to time, the progress of the baking may be watched: if it appears too rapid on one point, or too slow on another, the journeyman can, by means of the handle, bring the loaves successively to the hottest part of the oven, and vice versa, as occasion may require. The oven is provided with a thermometer, and, in an experiment witnessed, the temperature indicated 210° C. = 410° F., the baking of a full charge was completed in one hour and ten minutes, and the loaves of the same kind were so even in point of size and color that they could not be distinguished from each other.

The top of the oven is provided with a pan for the purpose of heating the water necessary for the preparation of the dough, by means of the heat which in all other plans (Mouchot's excepted) is lost. The workman should take care to keep always some water in that
pan, for otherwise the leaden pipe would melt and occasion dangerous leaks. For this and other reasons, the safest plan, however, would be to replace this leaden pipe by an iron one. The said pan should be frequently scoured, for, if neglected, the water will become rusty, and spoil the color of the bread. Bread-baking may be considered as consisting of four operations—namely, heating the oven, putting the dough into the oven, baking, and
BREAD.

Taking the loaves out of the oven. The general directions given by M. Rolland for each of these operations are as follows:—

In order to obtain a proper heat, and one that may be easily managed, it is necessary to charge the furnace moderately and often, and to keep it in a uniform state.

When the fire is kindled, the door should be kept perfectly closed, in order to compel the current of air necessary to the combustion to pass through the grate, and thence through the flues under and the dome over the oven. If, on the contrary, the furnace door were left open, the cold air from without would rapidly pass over the coals, without becoming properly heated, and, passing in that condition into the flues, would fail in raising it to the proper temperature. In order that the flame and heated products of the combustion may pass through all the flues, it is, of course, necessary to keep them clear by introducing into them once a month a brush made of wire, or whalebone, or those which are now generally used for sweeping the tubes of marine tubular boilers, and the best of which are those patented and manufactured by Messrs. Moriarty, of Greenwich, or How, of London. The vertical flues which are built in the masonry are cleared from without or from the pit, according to the nature of the plan adopted in building the oven. These flues need not be cleaned more often than about once in three months.

Sweeping between the floors should be performed about every fortnight.

In case of accident or injury to the thermometers, the following directions, which, indeed, apply to all ovens, may enable the baker to judge of the temperature of his oven:—

If, on throwing a few pinches of flour on the tiles of the oven, it remains white after the lapse of a few seconds, the temperature is too low; if, on the contrary, the flour assumes a deep brown color, the temperature is too high; if the flour turns yellowish, or looks slightly scorched, the temperature is right.

The baking in Rolland's oven takes place at a temperature varying from 410° to 452° F., according to the nature and size of the articles intended to be baked. During the baking, the revolving floor is turned every ten or twelve minutes, so that, the leaves not remaining in the same place, the baking becomes equal throughout.
BREAD.

As to the hot-water oven, two establishments only have as yet adopted it in England; one of them is the "Hot-water Oven Biscuit-baking Company," on whose premises fancy biscuits, etc., are baked; the second is at that of a baker of the name of Neville, carrying on his business in London. With respect to M. Mouchot's system, it is not even known in this country, otherwise than by having been alluded to in one or two technological publications or dictionaries.

The quantity of bread which can be made from a sack of flour depends to a great extent upon the quantity of gluten that the flour of which it is made contains, but the wheat which contains a large proportion of nitrogenous matter, does not yield so white a flour as those which are poorer. From a great number of determinations, it is found that the amount of gluten contained in the flour to make best white bread ranges from 10 to 18 per cent., that of the starch being from 63 to 70 per cent., the ashes ranging from 0·5 to 1·9 per cent.

This day, (17th of March, 1858,) the sack of genuine best household flour, weighing 280 lbs., delivered at the bakers' shop, costs 42s., and the number of sacks of flour converted weekly into bread by the London bakers is nearly 30,000, which gives about 12 sacks of flour per week as the average trade of each of them. The average capital of a baker doing that amount of business may be computed at £200, which, at 5 per cent., gives £15 interest; his rent may be estimated at about £55, and the rates, taxes, gas, and other expenses at about £25, in all £95, or very nearly £1 16s. 6d. per week, which sum, divided by 12, would give 3s. 9d. per sack.

In the ordinary plan of bread-making, London bakers reckon that 1 sack of such flour, weighing 280 lbs., will make 90 real 4-lb. loaves (not quarters) of pure, genuine bread, although a sack of such flour may yield him 94 or even 95 quarters (not 4-lb.) loaves.*

From this account it may be easily imagined that if the baker could succeed in disposing at once of all the loaves of his day's baking either by sale at his shop, or, still better, by delivery at his customers' residences, such a business would indeed be a profitable one, commercially speaking, for on that day he would sell from 28 to 34 lbs. of water at the price of bread, not to speak of the deficient weight; but, on the one hand, so many people provokingly require to have their loaves weighed at the shop, and are so stintingly particular about having their short weight made up; and, on the other hand, the loaves, between the first, second, and third day, do absolutely persist in letting their water evaporate, that the less weight is thus necessarily balanced by the profit obtained upon the loaves sold on the first day at the shop, or to those customers who have their bread delivered at their own door, to those who the baker knows, from position or avocations, will never take the trouble to verify the weight of his loaves, and who, he says, are gentlefolks, and no mistake about it.

As to those bakers who, by underbaking, or by the use of alum, or by the use of both alum and underbaking, manage to obtain 96, 98, 100, or a still larger number of loaves from inferior flour, or materials, their profit is so reduced by the much lower price at which they are compelled to sell their sophisticated bread, that their tamperings avail them but little; their emphatically hard labor yields them but a mere pittance, except their business be so extensive that the small profits swell up into a large sum, in which case they only jeopardize their name as fair and honest tradesmen.

Looking now at the improved ovens, of which we have been speaking merely in an economical point of view, and abstractedly from all other considerations, the profits realized by their use appears to be well worth the baker's attention. But as with the improved ovens the economy bears upon the wages and the fuel, the advantages are much less considerable in a small concern than in a large one. Thus, the economy which, upon 12 sacks of flour per week, would scarcely exceed 20 shillings upon the whole, would, on the contrary, assume considerable proportions in establishments baking from 50 to 100 sacks per week. We give here the following comparative statements of converting flour into bread at the rate of 70 sacks per week, from documents which may be fully relied upon. 70 sacks of flour manufactured into genuine bread, in the ordinary way, would yield 6,300 real 4-lb. loaves, and the account would stand as follows, taking 90 loaves, weighing really 4 lbs., as the ultimate yield of 1 sack of good household flour, of the quality and price above alluded to:—

**By the Ordinary Process.**

<table>
<thead>
<tr>
<th>Returns.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6,300 loaves (4 lbs.) at 7d.</td>
<td>£ 6 15 0</td>
</tr>
</tbody>
</table>

*It is absolutely necessary thus to establish a distinction between four-pounds and quarter loaves, because the latter very seldom indeed have that weight, and this deficiency is, in fact, one of the points calculated upon; for, although the Act of Parliament (Will. IV. cap. xxxvii.) is very strict, and directs (sect. vii.) that bakers delivering bread by cart or carriage shall be provided with scales, weights, &c., for weighing bread, this requisition is seldom, if ever, complied with. There are, of course, a few bakers whose quarter loaves weigh exactly four pounds, but the immense majority are from four to six ounces short.
BREAD.

EXPENSES.

<table>
<thead>
<tr>
<th>Item</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 sacks of household flour at 37s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coals, gas, potatoes, yeast, salt, wages, and other baking expenses, at 5s. per sack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent, taxes, interest of capital, and general expenses</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Net profit on 1 week's baking

By Perkins's Process.

RETURNS.

<table>
<thead>
<tr>
<th>Item</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,300 loaves (4 lbs.) at 7d.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXPENSES.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 sacks of flour at 37s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yeast, potatoes, and salt, at 1s. per sack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coals at 6d. per sack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages of a man per week</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 workman</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 hand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wear and tear, and repairs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent, interest on capital, (£1,500), taxes, gas, waste, and general expenses, per week</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

163 12 0

£21 13 0

In Roland's process the profits are very nearly the same as in that of Perkins, except the amount of fuel consumed is still more reduced, and does not amount, it is stated, to more than 4½d. per sack, which, for 70 sacks, is £1 6s. 3d., instead of £1 15s., or 9s. difference between the two methods for baking that quantity of flour.

The richness or nutritive powers of sound flour, and also of bread, are proportional to the quantity of gluten they contain. It is of great importance to determine this point, for both of these objects are of enormous value and consumption; and it may be accomplished most easily and exactly, by digesting, in a water-bath, at the temperature of 167° C., 1,000 grains of bread (or flour) with 1,000 grains of bruised barley malt, in 5,000 grains, or in a little more than half a pint, of water. When this mixture ceases to take a blue color from iodine, (that is, when all the starch is converted into a soluble dextrine,) the gluten left unchanged may be collected on a filter cloth, washed, dried at a heat of 212° F., and weighed. The color, texture, and taste of the gluten ought also to be examined, in forming a judgment of good flour or bread.

The question of the relative value of white and of brown bread, as nutritive agents, is one of very long standing, and the arguments on both sides may be thus resumed:

The advocates of brown bread hold—
That the separation of the white from the brown parts of wheat grain, in making bread, is likely to be beneficial to health;
That the general belief that bread made with the finest flour is the best, and that whiteness is a proof of its quality, is a popular error;
That whiteness may be, and generally is, communicated to bread by alum, to the injury of the consumer.

That the miller, in refining his flour, to please the public, removes some of the ingredients necessary to the composition and nourishment of the various organs of our bodies; so that fine flour, instead of being better than the meal, is, on the contrary, less nourishing, and, to make the case worse, is also more difficult of digestion, not to speak of the enormous loss to the population of at least 25 per cent. of branmy flour, containing from 60 to 70 per cent. of the most nutritious part of the flour, a loss which, for London only, is equal to at least 7,500 sacks of flour annually;

That the wise preference given so universally to white bread, leads to the pernicious practice of mixing alum with the flour, and this again to all sorts of impositions and adulterations; for it enables the bakers who are so disposed, by adding alum, to make bread manufactured from the flour of inferior grain to look like the best and more costly, thus defrauding the purchaser, and tampering with his health.

On the other side, the partisans of white bread contend, of course, that all these assertions are without foundation, and their reasons were summed up as follows in the Bakers' Gazette, in 1849:—
"The preference of the public for white bread is not likely to be an absurd prejudice, seeing that it was not until after years of experience that it was adopted by them. The adoption of white bread, in preference to any other sort, by the great body of the community, as a general article of food, is of itself a proof of its being the best and most nutritious."

"The finer and better the flour, the more bread can be made from it. Fifty-six pounds of fine flour from good wheat will make seventy-two pounds of good, sound, well-baked bread, the bread having retained sixteen pounds of water. But bran, either fine or coarse, absorbs little or no water, and adds no more to the bread than its weight."

And lastly, in confirmation of the opinion that white bread contains a greater quantity of nutriment than the same weight of brown bread, the writer of the article winds up the white bread defence with a portion of the Report of the Committee of the House of Commons, appointed in 1809, "to consider means for rendering more effectual the provisions of 13 Geo. III., intituled 'An Act for the better regulating the sale and making of Bread.'"

In considering the propriety of recommending the adoption of further regulations and restrictions, they understood a prejudice existed in some parts of the country against any coarser sort of bread than that which is at present known by the name of "fine household bread," on the ground that the former was less wholesome and nutritious than the latter. The opinions of respectable physicians examined on this point are,—that the change of any sort of food which forms so great a part of the sustenance of man, might, for a time, affect some constitutions; that as soon as persons were habituated to it, the standard wheaten bread, or even bread of a coarser sort, would be equally wholesome with the fine wheaten bread which is now generally used in the metropolis; but that, in their opinion, the fine wheaten bread would go farther with persons who have no other food than the same quantity of bread of a coarser sort.

It was suggested to them, that if only one sort of flour was permitted to be made, and a different mode of dressing it adopted, so as to leave it in the fine pollards, 52 lbs. of flour might be extracted from a bushel of wheat weighing 60 lbs., instead of 47 lbs., which would afford a wholesome and nutritious food, and add to the quantity 5 lbs. in every bushel, or somewhat more than 1/. On this they remarked that there would be no saving in adopting this proposition; and they begged leave to observe, if the physicians are well founded in their opinions, that bread of coarser quality will not go equally far with fine wheaten bread, an increased consumption of wheaten bread would be the consequence of the measure.

From the bakers' point of view, it is evident that all his sympathies must be in favor of the water-absorbing material, and therefore of the fine flour; for each pound of water added and retained in the bread which he sells, represents this day so many twopences; but the purchaser's interest lies in just the opposite direction.

The question, however, is not, in the language of the Committee of the House of Commons of those days, or of the physicians whom they consulted, whether a given weight of wheaten bread will go farther than an equal weight of bread of a coarser sort; nor whether a given weight of pure flour is more nutritious than an equal weight of the meal from the same wheat used in making-brown bread. The real question is,—Whether a given weight of wheat contains more nutriment than the flour obtained from that weight of wheat.

The inquiry of the Committee of the House of Commons, and the defence of white bread versus brown bread, resting, as it does, in this respect, upon a false ground, is therefore perfectly valueless; for whatever may have been the opinion of respectable physicians and of committees, either of those days or of the present times, one thing is certain,—namely, that bran contains only 9 or 10 per cent. of woody fibre, that is, of matter devoid of nutritious property; and that the remainder consists of a larger proportion of gluten and starch, fatty, and other highly nutritive constituents, with a few salts, and water, as proved by the following analysis by Millon:

<table>
<thead>
<tr>
<th>Composition of Wheat Bran.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>52.0</td>
</tr>
<tr>
<td>Gluten</td>
<td>14.9</td>
</tr>
<tr>
<td>Sugar</td>
<td>1.0</td>
</tr>
<tr>
<td>Fatty matter</td>
<td>2.0</td>
</tr>
<tr>
<td>Woody</td>
<td>9.7</td>
</tr>
<tr>
<td>Salts</td>
<td>5.0</td>
</tr>
<tr>
<td>Water</td>
<td>13.8</td>
</tr>
</tbody>
</table>

100.0

And it is equally certain that wheat itself—I mean the whole grain—does not contain more than 2 per cent. of un nutritious, or woody matter, the bran being itself richer, weight for weight, in gluten, than the fine flour; the whole meal contains, accordingly, more gluten than the fine flour obtained therefrom. The relative proportions of gluten
BREAD.

in the whole grain, in bran, and in flour of the same sample of wheat, were represented by the late Professor Johnston to be as follows:—

<table>
<thead>
<tr>
<th>Gluten of Wheat.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole grain</td>
<td>12</td>
</tr>
<tr>
<td>Whole bran</td>
<td>14</td>
</tr>
<tr>
<td>Fine flour</td>
<td>10</td>
</tr>
</tbody>
</table>

Now, whereas a bushel of wheat weighing 60 lbs. produces, according to the mode of manufacturing flour for London, 47 lbs.—that is, 78 per cent. of flour; the rest being bran and polishing; if we deduct 2 per cent. of woody matter, and 1\% per cent. for waste in grinding at the mill, the bushel of 60 lbs. of wheat would yield 58 lbs., or at least 96\% per cent. of nutritious matter.

It is, therefore, as clear as any thing can possibly be, that by using the whole meal instead of only the fine flour of that wheat, there will be a difference of about \(\frac{1}{3}\). In the product obtained from bran weights of wheat.

In a communication made to the Royal Institute nearly four years ago, M. Mège Mourières announced that he had found under the envelope of the grain, in the internal part of the perisperm, a peculiar nitrogenous substance capable of acting as a ferment, and to which he gave the name of "céraleine." This substance, which is found wholly, or almost so, in the bran, but not in the best white flour, has the property of liquefying starch, very much in the same manner as diastase; and the decreased firmness of the crumb of brown bread is referred by him to this action. The coloration of bread made from meal containing bran is not, according to M. Mège Mourières, due, as has hitherto been thought, to the presence of bran, but to the peculiar action of cerealin; this new substance, like vegetable casein and gluten, being, by a slight modification, due perhaps to the contact of the air, transformed into a ferment, under the influence of which the gluten undergoes a great alteration, yielding, among other products, ammonia, a brown-colored matter analogous to umin, and a nitrogenous product capable of transforming sugar into lactic acid. M. Mège Mourières having experimentally established, to the satisfaction of a committee consisting of MM. Chevreul, Dumas, Pelouze, and Pellegrin, that by paralyzing or destroying the action of cerealin, as described in the specification of his patent, bearing date the 14th of June, 1836, white bread, having all the characters of first quality bread, may be made, in the language of the said specification, "with using either all the white or raw elements that constitute either corn or rye, or with such substances as could produce, to this day, but brown bread."

Cerealin, according to M. Mège Mourières, has two very distinct properties:—the first consists in converting the hydrated starch into glucose and dextrine; the second, which is much more important in its results, transforms the glucose into lactic, acetic, butyric, and formic acid, which penetrate, swell up, and partly dissolve the gluten, rendering it pulpy and emulsive, like that of rye; producing, in fact, a series of decompositions, yielding eventually a leaf having all the characteristics of bread made from inferior flour.

In order to convert the whole of the farinaceous substance of wheat into white bread, it is therefore necessary to destroy the cerealin; and the process, or series of processes, by which this is accomplished, is thus described by M. Mège Mourières in his specification:—

"The following are the means I employ to obtain my new product:

1st. The application of vinous fermentation, produced by alcoholic ferment or yeast, to destroy the ferment that I call 'céraleine,' existing, together with the fragments of bran, in the raw flour, and which, in some measure, produces the acidity of brown bread directly, whilst it destroys indirectly most part of the gluten.

2ndly. The thorough purification of the said flour, either raw or mixed with bran, (after dilution and fermentation,) by the sifting and separating of the farinaceous liquid from the fragments of bran disseminated by the millstone into the inferior products of corn.

3rdly. The employing that part of corn producing brown bread in the rough state, as issuing from the mill after a first grinding, in order to facilitate its purification by fermentation and wet sifting.

4thly. The employing acidulated water (by any acid or acid salt) in order to prevent the lactic fermentation, preserving the vinous fermentation, preventing the yellow color from turning into a brown color, (the umic acid,) and the good taste of corn from assuming that of brown bread. However, instead of acidulated water, pure water may be employed with an addition of yeast, as the acid only serves to facilitate the vinous fermentation.

5thly. The grinding of the corn by means of millstones that crush it thoroughly, increasing thereby the quantity of foul parts, a method which will prove very bad with the usual process, and very advantageous with mine.

6thly. The application of corn washed or stripped by any suitable means.

7thly. The application of all these contrivances to wheat of every description, to rye, and other grain used in the manufacture of bread.

8thly. The same means applied to the manufacture of biscuits.

I will now describe the manner in which the said improvements are carried into effect.
BREAD

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"First Instance. When flour of inferior quality is made use of.—This description of flour, well known in trade, is boiled or sifted at 73, 75, or 80 per cent., (a mark termed *Scission mark* in the French War Department,) and yields bread of middle quality. By applying to this sort of flour a liquid yeast, rather different from that which is applied to white flour, in order to quicken the work and remove the sour taste of bread, a very nice quality will be obtained, which result was quite unknown to everybody to this day, and which none ever attempted to know, as none before me were aware of the true causes that produce brown bread, &c.

"Now, to apply my process to the said flour, (of inferior mark or quality,) I take a part of the same—a fourth part, for instance—which I dilute with a suitable quantity of water, and add to the farinaceous liquid 1 portion of beer yeast for 200 portions of water, together with a small quantity of acid or acid salt, sufficient to impart to the said water the property of lightly staining or reddening the test-paper, known in France by the name of *papier de tournesol.* When the liquid is at full working, I mix the remaining portions of flour, which are kneaded, and then allowed to ferment in the usual way. The yeast applied, which is quite alcoholic, will yield perfectly white bread of a very nice taste; and I declare that if similar yeasts were ever commended before, it was certainly not for the purpose of preventing the formation of brown bread, the character of which was believed to be inherent to the nature of the very flour, as the following result will sufficiently prove it, thus diverting such an application of its industrial appropriation.

"Second Instance. When raw flour is made use of.—By raw flour, I mean the corn crushed only once, and from which 10 to 15 per cent. of rough bran have been separated. Such flour is still mixed with fragments of bran, and is employed in trade to the manufacture of so-called white flour and bran after a second and third grinding or crushing. Instead of that, I only separate, and without submitting it to a fresh crushing, the rough flour in two parts, about 79 parts of white flour and 18 to 18 of rough or coarse flour, of which latter the yeast is made; this I dilute with a suitable quantity of water, sufficient to reduce the whole flour into a dough, say 60 per cent. of the whole weight of raw flour. To this mixture have been previously added the yeast and acid, (whenever acid is applied, which is not indispensable, as before stated,) and the whole is allowed to work for 6 hours at a temperature of 77° F., for 12 hours at 68°, and for 20 hours at 59°, thus proportionally to the temperature. While this working or fermentation is going on, the various elements (céréline, &c.) which, by their peculiar action, are productive of brown bread, have undergone a modification; the rough parts are separated, the gluten stripped from its pellicles and disaggregated, and the same flour which, by the usual process, could have only produced deep brown bread, will actually yield first-rate bread, far superior to that sold by bakers, chiefly if the fragments of bran are separated by the following process, which consists in pouring on the sieve, described hereafter, the liquid containing the rough parts of flour thus disaggregated and modified by a well-regulated fermentation.

"The sieve alluded to, which may be of any form, consists of several tissues of different thickness, the closest being ever arranged underneath or the most forward, when the sieve is of cylindrical or vertical form, is intended to keep back the fragments of bran, which would, by their interposition, impair the whiteness of bread, and, by their weight, diminish its nutritive power. The sifted liquid is white, and constitutes the yeast with which the white flour is mixed after being separated, so as to make a dough at either a first or several workings, according to the baker's practice. This dough works or ferments very quickly, and the bread resulting therefrom is unexceptionable. In case the whiteness or neatness of bread should be looked upon as a thing of little consequence, a broader sieve might be employed, or even no sieve used at all, and yet a very nice bread be obtained.

"The saving secured by the application of my process is as follows:—By the common process, out of 100 parts of wheat, 70 or 75 parts of flour are extracted, which are fit to yield either white or middle bread; whilst, by the improved process, out of 100 parts of wheat, 85 to 88 parts will be obtained, yielding bread of superior quality, of the best taste, neatness, and nutritious richness.

"In case new yeast cannot be easily provided, the same should be dried at a temperature of about 88° F., after being suitably separated by means of some inert dust, and previous to being made use of, it should be dipped into 10 parts of water, lightly sweetened, for 8 to 10 hours, a fit time for the liquid being brought into a full fermentation, at which time the yeast has recovered its former power. The same process will hold good for manufacturing rye bread, only 25 per cent., about, of course bran are to be extracted. For manufacturing biscuits, I use also the same process, only the dough is made very hard, and immediately taken into the oven, and the products thus obtained are far superior to the common biscuits, both for their good taste and preservation. Should, however, an old practice exclude all manner of fermentation, then I might dilute the rough parts of flour in either acidulated or non-acidulated water, there to be left to work for the same time as before, then sift the water and decant it, after a proper settling of the farinaceous matters of which the dough is to be made; thus the action of the acid, decantation, and sitting, would
effectively remove all causes of alteration, which generally impair the biscuits made of inferior flour.

The apparatus required for this process is very plain, and consists of a kneading-trough, in which the foul parts are mixed mechanically, or by manual labor, with the liquid above mentioned. From this trough, and through an opening made therein, the liquid mixture drops into the fermenting tub, deeper than wide, which must be kept tightly closed during the fermenting work. At the lower part of this tub a cock is fitted, which lets the liquid mixture down upon an inclined plane, on which the liquid spreads, so as to be equally distributed over the whole surface of the sieve. This sieve, of an oblong rectangular form, is laid just beneath, and its tissue ought to be so close as to prevent the least fragments of bran from passing through; it is actuated by the hand, or rather by a crank. In all cases, that part of the sieve which is opposite to the cock must strike upon an unyielding body, for the purpose of shaking the pellets remaining on the tissue, and driving them down towards an outlet on the lower part of the sieve, and thence into a trough purposely contrived for receiving the waters issuing from the sieve, and discharging them into a tank.

The next operation consists in diluting those pellets, or rougher parts, which could not pass through the sieve, sifting them again, and using the white water resulting therefrom to dilute the foul parts intended for subsequent operations. The sieve or sieves may sometimes happen to be obstructed by some parts of gluten adhering thereto, which I wash off with acidulated water for silk tissues, and with an alkali for metallic ones. This washing method I deem very important, as its non-application may hinder a rather large operation, and therefore I wish to secure it. This apparatus may be liable to some variations, and admit of several sieves superposed, and with different tissues, the broadest, however, to be placed uppermost.

Among the various descriptions and combinations of sieves that may be employed, the annexed figures show one that will give satisfactory results:

"Fig. 87 is a longitudinal section, and fig. 88 an end view, of the machine from which
the bran is ejected. The apparatus rests upon a cast-iron framing, a, consisting of two
cheeks, kept suitably apart by tie pieces, b; a strong cross-bar on the upper part admits a
wood cylinder, c, circled round with iron, and provided with a wooden cock, d. The cylin-
der, e, receives through its centre an arbor, f, provided with four arms, e, which arbor is sup-
ported by two cross-bars, g and h, secured by means of bolts to the uprights, i. Motion is
 imparted to the arbor, f, by a crank, j, by pulleys driven by the endless straps, k, and by
the toothed wheel, l, gearing into the wheel, m, which is keyed on the upper end of the ar-
bor, f. Beneath the cylinder, e, two sieves, n and o, are borne into a frame, p, suspended
on one end to two chains, q, and on the other resting on two guides or bearings, r, beneath
which, and on the crank shaft, are cams, s, by which that end of the frame that carries the
sieves is alternately raised and lowered. A strong spring, u, is set to a shaft borne by the
framing, e, whilst a ratchet-wheel provided with a clink, allows the said spring, according
to the requirements of the work, to give more or less impulse or shaking to the cams, s, are
acting upon the frame-sieve carrying the sieve. Beneath the said frame a large hopper, t,
BREAD.

is disposed, to receive and lead into a tank the liquid passing through the sieves. The filter sieve is worked as follows:—After withdrawing, by means of bolting hutch, 70 per cent., about, of fine flour; I take out of the remaining 30 per cent. about 20 per cent. of greats, neglecting the remaining 10 per cent., from which, however, I could separate the little flour still adhering thereto, but I deem it more available to sell it off in this state. I submit the 20 per cent. of greats to a suitable vinous fermentation, and have the whole taken into the cylinder, $c$, there to be stirred by means of the arbor, $f$; and the arurs, $e$; after a suitable stirring, the cock, $d$, is opened, and the liquid is let out, spread on the uppermost sieve, $n$, which keeps back the coarsest bran. The liquid drops then into the second sieve or filter, $o$, by which the least fragments are retained; the passage of the liquid through the filters is quickened by the quivering motion imparted by the cams, $s$, to the frame carrying the sieve."

The advantages resulting from such a process are obvious: first, it would appear—and those experiments have been confirmed by the committee of the Académie des Sciences, who had to report upon them—that no less than from 16 to 17 per cent. of white bread of superior quality can be obtained from wheat, which increase is not due to water, as in other methods, but is a true and real one, the Commissioners having ascertained that the bread thus manufactured did not contain more water than that made in the usual way, their comparative examinations in this respect having given the following results:—

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Old method</td>
<td>37.8</td>
<td>12.0</td>
</tr>
<tr>
<td>New method</td>
<td>37.5</td>
<td>14.0</td>
</tr>
</tbody>
</table>

| Difference            | 0.3    |

Another experiment by Peligot:—

<table>
<thead>
<tr>
<th>Loss by drying in Air at 248° F.</th>
<th>Crumb and Crust.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old method</td>
<td>34.9 per cent.</td>
</tr>
<tr>
<td>New method</td>
<td>34.1</td>
</tr>
</tbody>
</table>

| Difference                      | 0.8               |

Since the enrolment of his Specification, however, M. Mège Mouries has made an improvement, which simplifies considerably his original process, according to which the desire of the flour, as we saw, was effected by ordinary yeast; that is to say, by alcoholic fermentation. The last improvement consists in preventing cerealin from becoming a lactie or glucosic ferment, by precipitating it with common salt, and not allowing it time to become a ferment. In effect, in order that cerealin may produce the objectionable effects alluded to, it must first pass into the state of ferment, and, as all nitrogenuous substances require a certain time of incubation to become so, it, on the one hand, cerealin be precipitated by means of common salt, the glucosic action is neutralized; whilst, on the other hand, the levains being made with flour containing no cerealin—that is to say, with best white flour—if a short time before baking households or seconds are added thereto, it is clear that time will be wanting for it (the ferment) to become developed or organized, and that, under this treatment, the bread will remain white.

The application of these scientific deductions will be better understood by the following description of the process:—

100 parts of clean wheat are ground and divided as follows:—

<table>
<thead>
<tr>
<th>Best whites for leaven</th>
<th>40.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>White greats, mixed with a few particles of bran</td>
<td>38.0</td>
</tr>
<tr>
<td>White greats, mixed with a larger quantity of bran</td>
<td>8.0</td>
</tr>
<tr>
<td>Bran (not used)</td>
<td>15.5</td>
</tr>
<tr>
<td>Loss</td>
<td>0.5</td>
</tr>
</tbody>
</table>

102.0

These figures vary, of course, according to the kind of wheat used, according to seasons, and according to the description of mill and the distance of the millstones used for grinding.

*In order to convert these products into bread," says M. Mège Mouries, "a leaven is to be made by mixing the 40 parts of best flour above alluded to, with 20 parts of water, and proceeding with it according to the mode and custom adopted in each locality. A leaven, no matter how prepared, being ready, the 8 parts of greats mixed with the larger quantity of bran above alluded to, are diluted in 45 parts of water, in which 0.6 parts of

* Communication of M. Mège Mouriès to the Académie des Sciences, January, 1858.
common salt have been previously dissolved, and the whole is passed through a sieve, which allows the flour and water to pass through, but retains and separates the particles of bran. The watery liquid so obtained has a white color, is flocculent, and loaded with cerealin; it no longer possesses the property of liquefying gelatinous starch, and weighs 38 parts, (the remainder of the water is retained in the bran, which has swelled up in consequence, and remains on the sieve.) The leaven is then diluted with that water, which is loaded with best flour, and is used for converting dough into dough; the dough is then divided into suitable portions, and, after allowing it to stand for one hour, it is finally put in the oven to be baked. As the operations just described take place at a temperature of 25° C. (= 77° F.), the one hour during which the dough is left to itself, is not sufficient for the cerealin to pass into the state of ferment, and the consequence is the production of white bread. Should, however, the temperature be higher than that, or were the dough allowed to be kept for a longer time before baking, the bread produced, instead of being white, would be so much darker, as the contact would have lasted longer. By this process, 100 parts in weight of wheat yield 136 parts of dough, and finally, 115 parts in weight of bread, instead of 100, which the same quantity of wheat would have yielded in the usual way. This is supposing that the grinding of the wheat has been effected with close-set millstones; if ground in the usual way, the average yield does not exceed 112 parts in weight of bread.

The substances which are now almost exclusively employed for adulterating bread are water, alone or incorporated with rice, or water and alum; other substances, however, are or have been occasionally used for the same purpose; they are, sulphate of copper, carbonate of magnesia, sulphate of zinc, carbonate of ammonia, carbonate and bicarbonate of potash, carbonate and bicarbonate of soda, chalk, plaster, lime, clay, starch, potatoes, and other fecula.

This retention of water into bread is secured by underbaking, by the introduction of rice and fecula, and of alum.

Underbaking is an operation which consists of keeping in the loaf the water which otherwise would escape while baking; it is, therefore, a process for selling water at the price of bread. It is done by introducing the dough into an oven unduly heated, whereby the gases contained in the dough at once expand, and swell it up to the ordinary dimensions, whilst a deep-burnt crust is immediately afterwards formed; which, inasmuch as it is a bad conductor of heat, prevents the interior of the loaf from being thoroughly baked, and at the same time opposes the free exit of the water contained in the dough, and which the heat of the oven partly converts into steam, while the crust becomes thicker and darker than it otherwise should be, a sensible loss of nutritive elements being sustained, at the same time, in the shape of pyrogenous products which are dissipated.

The proportion of water retained in bread by underbaking is sometimes so large, that a baker may thus obtain as much as 106 loaves from a sack of flour.

The addition of boiled rice to the dough is also pretty frequently used to increase the yield of loaves; this substance, in fact, absorbs so much water, that as many as 116 quarter loaves have thus been obtained from one sack of flour.

From a great number of experiments, made with a view to determine the normal quantity of water contained in the crumb of genuine bread, it is ascertained that it amounts, in new bread, from 38 at least to at most 47 per cent.

The quantity of water contained in bread is easily determined by cutting a slice of it, weighing 500 grains, for example, placing it in a small oven heated by a gas-burner or a lamp to a temperature of about 220° F., until it no longer loses weight; the difference between the first and last weighing (that is to say, the loss) indicating, of course, the amount of water.

Alum, however, is the principal adulterating substance used by bakers, almost without exception, in this metropolis; as was proved by Dr. Normanby, in his evidence before the Select Committee of the House of Commons, appointed in 1855, under the presidency of Mr. W. Schloefeld, to inquire into the adulteration of food, drinks, and drugs, which assertion was corroborated and established beyond doubt by the other chemists who were examined also on the subject.

The introduction of alum into bread not only enables the baker to give to bread made of flour of inferior quality the whiteness of the best bread, but to force and keep in it a larger quantity of water than could otherwise be done. We shall see presently that this fact has been denied, and on what grounds.

The quantity of alum used varies exceedingly; but no appreciable effect is produced when the proportion of alum introduced is less than 1 in 800 or 1,000, which is at the rate of 27 or 28 grains in a quater loaf. The use of alum, however, has become so universal, and the Act of Parliament which regulates the matter has so long been considered as a dead letter from the trouble, and chance of pecuniary loss which it entails on the prosecutor should his accusation prove unsuccessful, that but few, and until quite lately none, of the public officers would undertake the discharge of a duty most disagreeable in itself, and at the same time full of risk.
When alum is used in making bread, one of the two following things may happen: either the alum will be decomposed, as just said, in which case the alumina will, of necessity, be set free as soon as digestion will have decomposed the organic matter with which it was combined; and thus it is presumable that either alum will be re-formed in the stomach, or, then, according to Liebig, the phosphoric acid of the phosphates of the bread, uniting with the alumina of the alum, will form an insoluble phosphate of alumina, and the beneficial action of the phosphates will, consequently, be lost to the system; and since phosphoric acid forms with alumina a compound hardly decomposable by alkalis or acids, this may, perhaps, explain the indigestibility of the London bakers' bread, which strikes all foreigners.—

_Letters on Chemistry._

The last defence set up in behalf of alummed bread to be noticed, is, that, with certain descriptions of flour, bread cannot be made without it; that, by means of alum, a large quantity of flour is made available for human food, which, without it, must be withdrawn, and turned to some other less important uses, to the great detriment of the population, and particularly of the poor, who would be the first to suffer from the increase of the price of bread which such a withdrawal must fatally produce.

The process usually adopted for the detection of alum, is that known as Kuhlman's process, which consists in incinerating about 3,000 grains of bread, porphyricing the ashes so obtained, treating them by nitric acid, evaporating the mixture to dryness, and diluting the residue with about 300 grains of water, with the help of a gentle heat; without filtering, a solution of caustic potash is then added, the whole is boiled a little, filtered, the filtrate is tested with a solution of sal ammoniac, and boiled for a few minutes. If a precipitate is formed, it is not alumina, as hitherto thought, and stated by Kuhlman and all other chemists, but phosphate of alumina,—a circumstance of great importance, not only in testing for the presence of alumina, but for the determination of its amount, as will be shown further on, when entering into the details of the modifications which it is necessary to make to Kuhlman's process.

In a paper read in April, 1858, at the Society of Arts, Dr. Odling stated that out of 46 examinations of ashes furnished him by Dr. Gilbert, and treating them by the above process, he (Dr. Odling) obtained, to use his own words, "in 21 instances, the celebrated white precipitate said to be indicative of alumina and alum, so that, had these samples been in the manufactured instead of the natural state—had the wheat, for example, been made into flour—I should have been justified, according to the authority quoted, in pronouncing it to be adulterated with alum. But a subsequent examination of the precipitates I obtained, showed that in reality they were not due to alumina at all. Mr. Kuhlman's process, as above described, is possessed of rare merits: it will never fail in detecting alumina when present, and will often succeed in detecting it when absent also. The idea of weighing this _alla podrida_ of a precipitate, and from its weight calculating the amount of alum present, as is gravely recommended by great anti-adulteration adepts, is too preposterous to require a moment's refutation."

Having stated the question in dispute as it at present stands, we must leave it to be discussed in another place.

In order, however, to render the process for the detection of alum in bread free from objections, the following method is recommended. It requires only ordinary care, and it is perfectly accurate:

_Cut the loaf in half; take a thick slice of crumb from the middle, carefully trimming the edges so as to remove the crust, or hardened outside, and weigh off 1,500 or 3,000 grains of it; crumbling it to powder, or cut it into slices, and expose them, on a sheet of platinum tray turned up at the edges, to a low red heat, until fumes are no longer evolved, and the whole is reduced to charcoal, which will require from twenty to forty minutes, according to the quantity; transfer the charcoal to a mortar, and reduce it to fine powder; put now this finely-pulverized charcoal back again on the platinum foil tray, and leave it exposed thereon to a dark cherry-red heat until reduced to grey ashes, for which purpose gas-furnace lamps will be found very convenient. Only a cherry-red heat should be applied, because at a higher temperature the ashes might fuse, and the incineration be thus retarded. Remove the source of heat, drench the grey ashes with a concentrated solution of nitrate of ammonia, and carefully reapply the heat; the last portions of charcoal will thereby be burnt, and the ashes will then have a white or drab color. Drench them on the tray with moderately strong and pure hydrochloric acid, and after one or two minutes' standing, wash the contents of the platinum foil tray with distilled water, into a porcelain dish; evaporate to perfect dryness, in order to render the silice insoluble; drench the perfectly dry residue with strong and pure muriatic acid, and, after standing for five or six minutes, dilute the whole with water, and boil; while boiling, add carefully as much carbonate of soda as is necessary nearly, but not quite, to saturate the acid, so that the liquor may still be acid; add as much pure alcohol-potash as is necessary to render it strongly alkaline; boil the whole for about three or four minutes, and filter. If now, after slightly supersaturating the strongly alkaline filtrate with pure muriatic acid, the further addition of a solution of car-
bonate of ammonia produces, either at once or after heating it for a few minutes, a light, white flocculent precipitate, it is a sign of the presence of alumina, the identity of which is confirmed by collecting it on a filter, putting a small portion of it on a platinum hook, or on charcoal, heating it thereon, moistening the little mass with nitrate of cobalt, and again strongly heating it before the blowpipe; when, if, without fusing, it assumes a beautiful blue color, the presence of alumina is corroborated. If the operator possesses a silver capsule, he will do well to use it instead of a porcelain one for boiling the mass with pure caustic alcohol-potash, in order to avoid all chance of any silica (from the glass) becoming dissolved by the potash, and afterwards simulating the presence of alumina, though, if the boiling be not protracted, a porcelain capsule is quite available. It is, however, absolutely necessary that he should use potasse a l'alcool, for ordinary caustic potash always contains some, and occasionally considerable, quantities of alumina, and is totally unsuited for such an investigation. Even potasse a l'alcool retains traces of silica, either alone, or combined with alumina; so that for this, and other reasons which will be explained presently, an extravagant quantity of it should not be used.

Lastly, carbonate of ammonia is preferable to caustic ammonia for precipitating the alumina, since that earth is far from being insoluble in caustic ammonia.

The liquor in which the alumina has been separated should now be acidified with hydrochloric acid, and tested with chloride of barium, which should then yield a copious precipitate of sulphate of barytes.

The only precipitate which can, under the circumstances of the experiment, simulate alumina, is the phosphate of that earth, which behaves with all reagents as pure alumina. Such a precipitate, therefore, if taken account of as pure alumina, would altogether vitiate a qualitative analysis if the amount of alum were calculated from it; but the proof that a certain quantity of alum had been used in the bread from which it had been obtained would remain unshaken; since alumina, whether in that state or in that of its phosphate, could not have been found except a salt of alumina—to wit, alum—had been used by the baker.

When, therefore, the exact amount of alumina has to be determined, the precipitate in question should be submitted to further treatment in order to separate the alumina; and this can be done easily and rapidly by dissolving the precipitate in nitric acid, adding a little metallic tin to the liquor, and boiling. The tin becomes rapidly oxidized, and remains in the state of an insoluble white powder, which is a mixture of peroxide of tin and of phosphate of tin, at the expense of all the phosphoric acid of any earthy phosphate which may have been present. The whole mass is evaporated to dryness, and the dry residue is then treated by water and filtered, in order to separate the insoluble white powder, and the filtrate which contains the alumina should now be supersaturated with carbonate of ammonia. If a precipitate is formed, it is pure alumina. The white insoluble powder, after washing, may be dissolved in hydrochloric acid, and after diluting the solution with water, the tin may be precipitated therefrom by passing through it a stream of sulphuric acid to supersaturation, leaving at rest for ten or twelve hours, filtering, boiling the filtrate until all the excess of sulphuric acid has disappeared; an excess of nitrate of silver is then added, and the liquor filtered, to separate the chloride of silver produced, and exactly neutralizing the filtrate with ammonia; and if a lemon-yellow precipitate is produced, immediately soluble in the slightest excess of either ammonia or nitric acid, it is basic phosphate of silver, (3AgO) PO₄, the precipitate obtained in the first instance being thus proved to be phosphate of alumina. The pure alumina obtained may now be collected on a filter, washed with boiling water, thoroughly dried, and then ignited and weighed. One grain of alumina represents 9.027 grains of crystallized alum.

In testing bread for alum, it should be borne in mind, however, that the water used for making the dough generally contains a certain quantity of sulphates, and that a precipitate of sulphate of barytes will therefore be very frequently obtained, though much less considerable than when alum has been used. Some waters called "scelentious" contain so much sulphate of lime in solution, that if they were used in making the dough, chloride of barium would afford, of course, a considerable precipitate. For these reasons, therefore, the separation and identification of alumina are the only reliable proofs; because, as that earth does not exist normally in any shape in wheat or common salt otherwise than in traces, the proof that alum has been used becomes irresistible when we find, on the one hand, alumina, and, on the other, a more considerable amount of sulphate of barytes than, except under the most extraordinary circumstances, genuine bread would yield.

Sulphate of copper, like alum, possesses the property of hardening gluten, and thus, with a flour of inferior quality, bread can be made of good appearance, as if a superior flour had been used.

Lime water has been recommended by Liebig as a means of improving the bread made from inferior flour, or of flour slightly damaged, by keeping, by warehousing, or during transport in ships; and this method, at the meeting of the British Association at Glasgow, in 1855, was reported as having been tried to a somewhat considerable extent by the bakers of that town, and with success, the bread kneaded with lime water, instead of pure water,
being of good appearance, good taste, good texture, and free from the sour taste which invariably belongs to alunied or even to genuine bread;—admitting all this to be true, still we should not depreciate the use of lime water in bread, because it cannot be done with impunity; however small the dose of additional matter may be considered when taken separately, it is always large when considered as portion of an article of food like bread, consumed day after day, and at each meal, without interruption. To allow articles of food to be tampered with, under any circumstances, is a dangerous practice, even if it were proved that it can be done without risk, which, however, is not the case; and Liebig himself has said that chemists should never propose the use of chemical products for culinary preparations.

The quantity of ashes left after the incineration of genuine bread, varies from 1.5 to at least 3 per cent.; and if the latter quantity of ashes be exceeded, the excess may safely be pronounced to be due to an artificial introduction of some saline or earthy matter. As to the addition to bread of potatoes, beans, rice, turnips, maize, or Indian corn, which has occasionally been practised to a considerable extent, especially in years of scarcity, it is evident that they may be, and are actually permitted under the Act of Parliament, Will. IV., cap. 27, sect. 11. As may be seen below, bread in which these ingredients replace a certain quantity of flour, is, of course, perfectly wholesome; but as a given weight of it contains less nourishment than pure wheat bread, it is clear that if the mixed bread were sold under the name, or at the price, of wheat bread, it would be a fraud on the public, and more especially upon the poor; but the admixture is not otherwise objectionable. In his "New Letters on Chemistry," Liebig makes the following remarks on the subject:

"The proposals which have hitherto been made to use substitutes for flour, and thus diminish the price of bread in times of scarcity, prove how much the rational principles of hygiene are disregarded, and how unknown the laws of nutrition are still."

"It is with food as with fuel. If we compare the price of the various kinds of coals, of wood, of turf, we shall find that the number of pence paid for a certain volume or weight of these materials is about proportionate to the number of degrees of heat they evolve in burning. . . . The mean price of food in a large country is ordinarly the criterion of its nutritive value. . . . Considered as a nutritive agent, rye is quite as dear as wheat; such is the case, also, with rice and potatoes; in fact, no other flour can replace wheat in this respect. In times of scarcity, however, these ratios undergo modification, and potatoes and rice acquire then a higher value, because, in addition to their natural value as respiratory food, another value is superadded, which, in times of abundance, is not taken into account.

"The addition to wheat flour of potato starch, of dextrine, of the pulp of turnips, gives a mixture, the nutritive value of which is equal to that of potatoes, or perhaps less; and it is evident that one cannot consider as an improvement this transformation of wheat flour into a food having only the same value as rice or potatoes. The true problem consists in communicating to rice and to potatoes a power equal to that of wheat flour, and not in doing the reverse. At all events it is always better to cook potatoes by themselves, and eat them, than with bread; the Legislature should even prohibit their addition to bread, on account of the fraud which the permission must inevitably lead to."

The detection of potato starch, of beans, peas, Indian corn, rice, and other cereals, which is so easily effected by means of the microscope in flour, is exceedingly difficult, if not impossible, in bread. Bread which has been made of flour mixed with Indian corn is harsher to the touch, and has frequently a slight yellowish color, and, when moistened with solution of potash of ordinary strength, a yellow or greenish-yellow tinge is developed.—A. N. BREWER. (Brasser, Fr.; Branca, Germ.) The art of making beer, or an alcoholic liquor, from a fermented infusion of some saccharine and amylaceous substance with water. For a description and analysis of which, and of the substances usually employed in its fermentation, see the article BEER.

The processes of brewing may be classed under three heads:—the mashing, the boiling, and the fermentation.

For the principles which should guide the brewer in the conduct of these operations, we refer to the article BEER, where it will be seen that the ultimate success of the entire series depends greatly on the regulation of the temperature, the duration, and the proper management of the initial process of mashing.

With regard to temperature, the brewer must not only regulate the heat of the water for the first mash by the color, age, and quality of the malt, whether pale, amber, or brown, but he should also mark the temperature of the atmosphere as influencing that of the malt, and the absorption of the heat by the utensils employed; reminding that well-flavored and brown malt will bear a higher mashing heat than pale or newly dried, and that the best results are produced when the mash can be maintained at an equable temperature, from 160° to 165°.

The duration of the mash must also have reference to the required quality of the beer, whether intended for keeping some time in store, or for present use, as influencing the

BREWING. 203
relative proportions of dextrine and sugar. The following table, by Leveaque, will exemplify the foregoing remarks.

The first column gives the temperature of the air at the time of mashing.

The second column shows the heat of the water, the quantity used, and the resulting heat of the mass—noting, that if the water has been let into the mash-tun, at the boiling point, and allowed to cool down, or the vessel has been thoroughly warmed before the commencement of the process, the heat may be taken several degrees lower.

The third column shows the time for the standing of the mash; but this will be modified, as before stated, by the quality of the extract required.

The bulk of the materials used must also enter into the consideration of the temperature, as a large body of malt will attain the required temperature with a mashing heat lower than a small quantity; the powers of chemical action and condensation of heat being increased with increase of volume.

Donovan, speaking of the temperature to be employed in mashing, lays down the following as a general rule:—For well-dried pale malt, the heat of the first mashing liquor may be, but should never exceed, 170°; the heat of the second may be 180°; and, for a third, the heat may be, but need never exceed, 185°.

The quantity of water, termed liquor, to be employed for mashing, depends upon the greater or less strength to be given to the beer, but, in all cases, from one barrel and a half to one barrel and three firkins is sufficient for the first still mashing, but more liquor may be added after the malt is thoroughly wetted.

The grains of the crushed malt, after the wort is drawn off, retain from 83 to 40 gallons of water for every quarter of malt. A further amount must be allowed for the loss by evaporation in the boiling and cooling, and the waste in fermentation, so that the amount of liquor required for the mashing will, in some instances, be double that of the finished beer, but in general the total amount will be reduced about one-third during the various processes.

### Table of Mashing Temperatures

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The following example will give an idea of the proportions for an ordinary quality of beer:

Suppose 13 imperial quarters of the best pale malt be taken to make 1,500 gallons of beer, the waste may be calculated at near 900 gallons, or 2,400 gallons of water will be required in mashing.

As soon as the water in the copper has attained the heat of 145° in summer, or 167° in winter, 600 gallons of it are to be run off into the mash-tub, (which has previously been well cleansed or scalded out with boiling water,) and the malt gradually but rapidly thrown in and well intermixed, so that it may be uniformly moistened, and that no lumps remain. After continuing the agitation for about half an hour, more liquor, to the amount of 450 gallons, at a temperature of 190°, may be carefully and gradually introduced, (it is an advantage if this can be done by a pipe inserted under the false bottom of the mash-tub,) the agitation being continued till the whole assumes an equally fluid state, taking care also to allow as small a loss of temperature as possible during the operation, the resulting temperature of the mass being not less than 143°, or more than 148°.
The mash is then covered close, and allowed to remain at rest for an hour, or an hour and a half, after which the top of the mash-tub is gradually opened, and if the wort that first flows is turbid, it should be carefully returned into the tub until it runs perfectly limpid and clear. The amount of this first wort will be about 675 gallons.

Seven hundred and fifty gallons of water, at a temperature from 180° to 185°, may now be introduced, and the mashing operation repeated and continued until the mass becomes uniformly fluid as before, the temperature being from 160° to 170°. It is then again covered and allowed to rest for an hour, and the wort of the first mash having been quickly transferred from the underback to the copper, and brought to a state of ebullition, the wort of the second mash is drawn off with similar precaution, and added to it. A third quantity of water, about 600 gallons, at a temperature of 185° or 190°, should now be run through the goods in the mash-tub by the sparging process, or any means that will allow the hot liquor to percolate through the grains, displacing and carrying down the heavier and more valuable products of the first two mashings. The wort is now boiled with the hops from one to two hours.

The object of boiling the wort is not merely evaporation and concentration, but extraction, coagulation, and, finally, combination with the hops; purposes which are better accomplished in a deep confined copper, by a moderate heat, than in an open, shallow pan, with a quick fire. The copper, being encased above in brickwork, retains its digesting temperature much longer than the pan could do. The waste steam of the close kettle, moreover, can be economically employed in communicating heat to water or weak worts; whereas the exhalations from an open pan would prove a nuisance, and would need to be carried off by a hood. The boiler has a four-fold effect: 1, it concentrates the wort; 2, during the earlier stages of heating, it converts the starch into sugar, dextrine, and gum, by means of the diastase; 3, it extracts the substance of the hops diffused through the wort; 4, it coagulates the albuminous matter present in the grain, or precipitates it by means of the tannin of the hops.

The degree of evaporation is regulated by the nature of the wort and the quality of the beer. Strong ale and stout, for keeping, require more boiling than ordinary porter or table-beer, brewed for immediate use. The proportion of the water carried off by evaporation is usually from a seventh to a sixth of the volume. The hops are introduced at the commencement of the process. They serve to give the beer not only a bitter aromatic taste, but also a keeping quality, or they counteract its natural tendency to become sour—an effect partly due to the precipitation of the albumen and starch, by their resonous and tanning constituents, and partly to the antifermentable properties of their lupuline, bitter principle, ethereous oil, and resin. In these respects, there is none of the bitter plants which can be substituted for hops with advantage. For strong beer, powerful fresh hops should be selected; for weaker beer, an older and weaker article will suffice.

The stronger the hops are, the longer time they require for extraction of their virtues; for strong beer, an hour and a half, or two hours' boiling may be proper; for a weaker sort, half an hour or an hour may be sufficient; but it is never advisable to push this process too far, lest a disagreeable bitterness, without aroma, be imparted to the beer. In some breweries, it is the practice to boil the hops with a part of the wort, and to filter the decoction through a drain, called the jack hop-back. The proportion of hops to malt is very various; but, in general, from 1 lb. to 1½ lbs. of the former are taken for 100 lbs. of the latter in making good table beer. For porter and strong ale, 2 lbs. of hops are used, or even more; for instance, from 2 lbs. to 2½ lbs. of hops to a bushel of malt, if the beer be destined for the consumption of India.

During the boiling of the two ingredients, much coagulated albuminous matter in various states of combination, makes its appearance in the liquid, constituting what is called the breaking or curdling of the wort, when numerous minute flocks are seen floating in it. The resonous, bitter, and oily-ethereous principles of the hops combine with the sugar and gum, or dextrine of the wort; but for this effect they require time and heat; showing that the boil is not a process of mere evaporation, but one of chemical reaction. A yellowish-green pellicle of hop-oil and resin appears upon the surface of the boiling wort, in a somewhat frothy form; when this disappears, the boiling is presumed to be completed, and the beer is strained off into the cooler. The residuary hops may be pressed and used for an inferior quality of beer; or they may be boiled with fresh wort, and be added to the next brewing charge.

After being strained from the hops, by passing through the false bottom of the hop-jack, and allowed to rest on the coolers a sufficient time to deposit the greatest portion of the hops separated, the cooling process is rapidly completed by the action of the Refrigerator. See Refrigeration of Worts, vol. ii.

The wort is then ready for the inoculation of the yeast and the commencement of the fermentative process, which completes the finished beer. See the articles Beer and Fermentation.

BREZILIN AND BREZILEIN. According to M. Preiser, the coloring matter of Brazil wood (Brezilia) is an oxide of a base Brezilein, which has no color.
BRICK. (Brique, Fr.; Backsteine, Ziegresteine, Germ.) A solid rectangular mass of baked clay, employed for building purposes.

The natural mixture of clay and sand, called loam, as well as marl, which consists of lime and clay with little or no sand, are the materials usually employed in the manufacture of bricks.

There are few places in this country which do not possess alumina in combination with silica and other earthy matters, forming a clay from which bricks can be manufactured. That most generally worked is found on or near the surface in a plastic state. Others are hard marls on the coal measure, new red sandstone, and blue clay formations. It is from these marls that the blue bricks of Staffordshire and the fire-bricks of Stourbridge are made. Marl has a greater resemblance to stone and rock, and varies much in color; blue, red, yellow, &c. From the greatly different and varying character of the raw material, there is an equal difference in the principle of preparation for making it into brick; while one merely requires to be turned over by hand, and to have sufficient water worked in to make it subservient to manual labor, the fire-clays and marls must be ground down to dust, and worked by powerful machinery, before they can be brought into even a plastic state. Now these various clays also shrink in drying and burning from 1 to 15 per cent., or more. This contraction varies in proportion to the excess of alumina over silica, but by adding sand, loam, or chalk, or (as is done by the London brick-makers) by using ashes or breeze—as it is technically called—this can be corrected. All clays burning red contain oxides of iron, and those having from 8 to 10 per cent., burn of a blue, or almost a black color. The bricks are exposed in the kilns to great heat, and when the body is a fire-clay, the iron, melting at a lower temperature than is sufficient to destroy the bricks, gives the outer surface of them a complete metallic coating. Bricks of this description are common in Staffordshire, and when made with good machinery, (that is, the clay being very finely ground,) and exposed to any in the kingdom, particularly for docks, canals or river locks, railway-bridges, and viaducts. In Wolverhampton, Dudley, and many other towns, these blue bricks are commonly employed for paving purposes. Other clays contain lime, and no iron; these burn white, and take less heat than any other to burn hard enough for the use of the builder, the lime acting as a flux on the silica. Many clays contain iron and lime, with the lime in excess, when the bricks are of a light dun color, or white, in proportion to the quantity of that earth present; if magnesia, they have a brown color. If iron is in excess, they burn from a pale red to the color of east-iron, in proportion to the quantity of metal.

There are three classes of brick earths:—

1st. Plastic clay, composed of alumina and silica, in different proportions, and containing a small percentage of other salts, as of iron, lime, soda, and magnesia.

2d. Loams, or sandy clays.

3d. Marl, of which there are also three kinds; clayey, sandy, and calcareous, according to the proportions of the earth of which they are composed, viz., alumina, silica, and lime.

Alumina is the oxide of the metal aluminium, and it is this substance which gives tenacity or plasticity to the clay-earth, having a strong affinity for water. It is owing to excess of alumina that many clays contract too much in drying, and often crack on exposure to the open air. By the addition of sand, this clay would make a better article than we often see produced from it. Clays contain magnesia and other earthy matters, but these vary with the stratum or rock from which they are composed. It would be impossible to give the composition of these clays correctly, for none are exactly similar; but the following will give an idea of the proportions of the ingredients of a good brick earth: silica, three-fifths; alumina, one-fifth; iron, lime, magnesia, soda, and potash forming the other one-fifth.

The clay, when first raised from the mine or bed, is, in very rare instances, in a state to allow of its being at once tempered and moulded. The material from which fire-bricks are manufactured has the appearance of ironstone and blue lias limestone, and some of it is remarkably hard, so that in this and many other instances, in order to manufacture a good article, it is necessary to grind this material down into particles as fine as possible.

Large quantities of bricks are made from the surface marls of the new red sandstone and blue lias formations. These also require thorough grinding, but from their softer nature it can be effected by less powerful machinery.—Chamberlain.

Recently, some very valuable fire-bricks have been made from the refuse of the China Clay Works, of Devonshire. The quartz and mica left after the Kiesel has been washed out, are united with a small portion of inferior clay, and made into bricks. These are found to resist heat well, and are largely employed in the construction of metallurgical works. See Clay.

The principal machines which have been worked in brick-making are three—1st, the pug-mill; 2d, the wash-mill; 3d, the rolling-mill.

The pug-mill is a cylinder, sometimes conical, generally worked in a vertical position, with the large end up. Down the centre of this is a strong revolving vertical shaft, on which are hung horizontal knives, inclined at such an angle as to form portions of a screw,
that is, the knives follow each other at an angle forming a series of coils round this shaft. The bottom knives are larger, and vary in form, to throw off the clay, in some mills vertically, in others horizontally. Some have on the bottom of the shaft one coil of a screw, which throws the clay off more powerfully where it is wished to give pressure.

The action of this mill is to cut the clay with the knives during their revolution, and so work and mix it, that on its escape it may be one homogeneous mass, without any lumps of hard untempered clay; the clay being thoroughly amalgamated, and in the toughest state in which it can be got by tempering. This mill is an excellent contrivance for the purpose of working the clay, in combination with rollers; but if only one mill is worked, it is not generally adopted, for, although it tempers, mixes, and toughens, it does not extract stones, crush up hard substances, or free the clay from all matters injurious to the quality of the ware when ready for market. This mill can be worked by either steam, water, or horse power; but it takes much power in proportion to the quantity of work which it performs.

If a brick is made with clay that has passed the pug-mill, and contains stones, or marl not acted on by weather, or lime-shells, (a material very common in clays,) or any other extraneous matter injurious to the brick, it is apparent from the action of this mill that it is not removed or reduced. The result is this: the bricks being, when moulded, in a very soft state of tempered material, or mud, considerably contract in drying, but the stones or hard substances not contracting, cause the clay to crack; and even if they should not be sufficiently large to do this in drying, during the firing of the bricks there is a still further contraction of the clay, and an expansion of the stone, from the heat to which it is subjected, and the result is generally a faulty or broken brick, and, on being drawn from the kilns, the bricks are found to be imperfect.

The earth, being sufficiently kneaded, is brought to the bench of the moulder, who works the clay into a mould made of wood or iron, and strikes off the superfluous matter. The bricks are next delivered from the mould, and ranged on the ground; and when they have acquired sufficient firmness to bear handling, they are dressed with a knife, and staked or built up in long dwarf walls, thatched over, and left to dry. An able workman will make, by hand, 5,000 bricks in a day.

The different kinds of bricks made in England are principally place bricks, grey and red stocks, marl facing bricks, and cutting bricks. The place bricks and stocks are used in common walling. The marls are made in the neighborhood of London, and used in the outside of buildings; they are very beautiful bricks, of a fine yellow color, hard, and well burnt, and, in every respect, superior to the stocks. The finest kind of marl and red bricks, called cutting bricks, are used in the arches over windows and doors, being rubbed to a centre, and gaged to a height.

Bricks, in this country, are generally baked either in a clamp or in a kiln. The latter is the preferable method, as less waste arises, less fuel is consumed, and the bricks are sooner burnt. The kiln is usually 13 feet long, by 10 feet wide, and about 12 feet in height. The walls are one foot two inches thick, carried up a little out of the perpendicular, inclined towards each other at the top. The bricks are placed on flat arches, having holes left in them resembling lattice-work; the kiln is then covered with pieces of tiles and bricks, and some wood put in, to dry them with a gentle fire.

This continues two or three days before they are ready for burning, which is known by the smoke turning from a darkish color to semi-transparency. The mouth or mouths of the kiln are now manned up with a shinlog, which consists of pieces of bricks piled one upon another, and closed with wet brick earth, leaving above it just room sufficient to receive a fagot. The fagots are made of furze, heath, bracken, fern, &c, and the kiln is supplied with these until its arches look white, and the fire appears at the top, upon which the fire is slackened for an hour, and the kiln allowed gradually to cool. This heating and cooling is repeated until the bricks are thoroughly burned, which is generally done in 48 hours. One of these kilns will hold about 20,000 bricks.

Clamps are also in common use. They are made of the bricks themselves, and generally of an oblong form. The foundation is laid with place brick, or the driest of those just made, and then the bricks to be burnt are built up, tier upon tier, as high as the clamp is meant to be, with two or three inches of breeze or cinders strewn between each layer of bricks, and the whole covered with a thick stratum of breeze. The fire place is perpendicular, about three feet high, and generally placed at the west end; and the flames are formed by gathering or arching the bricks over, so as to leave a space between each of nearly a brick wide. The flames run straight through the clamp, and are filled with wood, coals, and breeze, pressed closely together. If the bricks are to be burnt off quickly, which may be done in 20 or 30 days, according as the weather may suit, the flames should be only at about six feet distance; but if there be no immediate hurry, they may be placed nine feet asunder, and the clamp left to burn off slowly.

The following remarks by Mr. H. Chamberlain, on the drying of bricks, have an especial value from the great experience of that gentleman, and his careful observation of all the conditions upon which the preparation of a good brick depends:—
The drying of bricks ready for burning is a matter of great importance, and requires more attention than it generally receives. From hand-made bricks we have to evaporate some 25 per cent. of water before it is safe to burn them. In a week requiring the making of 20,000 bricks per day, we have to evaporate more than 20 tons of water every 24 hours. Hand-made bricks lose, in drying, about one-fourth of their weight, and in drying and burning about one-third. The average of machine bricks—those made of the stiff plastic clay—do not lose more than half the above amount from evaporation, and are, therefore, of much greater specific gravity than hand-made ones.

The artificial drying of bricks is carried on throughout the year uninterruptedly in sheds having the floor heated by fires; but this can only be effected in districts where coal is cheap. The floors of these sheds are a series of tunnels or flues running through the shed longitudinally. At the lower end is a pit, in which are the furnaces; the fire travels up the flues under the floor of the shed, giving off its heat by the way, and the smoke escapes at the upper end, through a series of (generally three or four) smaller chimneys or stacks. The furnace end of these flues would naturally be much more highly heated than the upper end near the chimneys. To remedy this, the floor is constructed of a greater thickness at the fire end, and gradually diminishes to within a short distance of the top. By this means, and by the assistance of dampers in the chimneys, it is kept at nearly an equal temperature throughout. Bricks that will bear rapid drying, such as are made from marly clays or very loamy or siliceous earths, will be fit for the kiln in from 12 to 24 hours. Before the duty was taken off bricks, much dishonesty was practised by unprincipled makers, where this drying could be carried on economically. Strong clays cannot be dried so rapidly. These sheds are generally walled round with loose bricks, stacked in between each post or pillar that supports the roof. The vapor given off from the wet bricks, rising to the roof, escapes. This system of drying is greatly in advance of that in the open air, for it produces the ware, as made, without any deterioration from bad weather; but the expense of fuel to heat these flues has restricted its use to the neighborhood of collieries. In 1845 attention was turned to the drying of bricks, and experiments carried out in drying the ware with the waste heat of the burning kilns. The calorific, after having passed the ware in burning, was carried up a flue raised above the floor of the shed, and gave off its spent heat for drying the ware. Although this kiln was most useful in proving that the waste heat of a burning kiln is more than sufficient to dry ware enough to fill it again, it was abandoned on account of the construction of the kiln not being good.

Another system of drying is in close chambers, by means of steam, hot water, or by flues heated by fire under the chambers. I will, therefore, briefly describe the steam chamber, as used by Mr. Beart. This is a square construction or series of tunnels or chambers, built on an incline of any desired length; and at some convenient spot near the lower end, is fixed a large steam boiler, at a lower level than the drying chamber. From the boiler the main steam pipe is taken along the bottom or lower end of the chamber, and from this main, at right angles, run branch pipes of four inches diameter up the chamber, two feet apart, and at about three feet from the top or arch. From there being so close and shallow a chamber between the heating surface of the pipes and the top, and so large an amount of heating surface in the pipes, the temperature of the pipes, the temperature at the top and bottom ends are shutters or lids, which open for the admission of the green ware at the upper end, and for the exit of the dry ware at the lower end of the chamber. Over the steam pipes are fixed iron rollers, on which the trays of bricks, as brought from the machine, are placed, the insertion of one tray forcing the tray previously put in further on, assisted in its descent by the inclination of the construction. The steam being raised in the boiler flows through the main into those branch pipes in the chamber, and from the large amount of exposed surface becomes condensed, giving off its latent heat. From the incline given to the pipes in the chamber, and from the main pipe also having a fall towards the boiler, the whole of the warm water from the condensed steam flows to the boiler to be again raised to steam, sent up the pipes, and condensed intermittently. The steam entering at the lower end of the chamber, it is, of course, warmer than the upper end. Along the top end or highest part of the chamber is a series of chimneys and wind-guards, through which the dump vapor escapes. The bricks from the machine enter at this cooler end charged with warm vapor, and as the make proceeds are forced down the chamber as each tray is put in. Thus, those which were first inserted reach a drier and warmer atmosphere, and, on their arrival at the lower end, come out dry bricks, in about 24 hours, with the strongest clays. In some cases the waste steam of the working engine is sent through these pipes and condensed. Bricks will dry soundly without cracking, &c., in these close chambers, when exposed to much greater heat than they would bear on the open flue first described, or the open air, from the circumstance of the atmosphere, although very hot, being so highly charged with vapor. In practice, these steam chambers have proved many principles, but they are not likely to become universal, for they are very expensive in erection on account of the quantity of steam pipes, and involve constant expense in fuel, and require attention in the management of the steam boiler; but their greatest defect is
the want of a current of hot air through the chamber to carry off the excess of vapor faster than is now done. The attaining a high degree of temperature in these chambers is useless, unless there is a current to carry off the vapor. Why should this piping be used, or steam at all, when we have a large mass of heat being constantly wasted, night and day, during the time the kilns are burning? and after the process of burning the kiln is completed, we have pure hot air flowing, from 48 to 60 hours, from the mass of cooling bricks in the kilns, free from carbon or any impurities; this could be directed through the drying chambers, entering in one constant flow of hot dry air, and escaping in warm vapor. The waste heat during the process of burning can be taken up flues under the chamber, and thereby all the heat of our burning kilns may be economized, and a great outlay saved in steam pipes, boilers, and attention. It must not be forgotten, also, that so large an atmospheric condenser as the steam chamber is not heated without a considerable expenditure in fuel. This drying by steam is a great stride in advance of the old flued shed, but practical men must see the immense loss incurred constantly from this source of the spent heat of the burning kilns, and that by economizing it, an immense saving will be effected in the manufacture.

The kilns are constructed as near the lower end of these chambers as convenient. Mr. Chamberlain must be again quoted on the burning of bricks. I will now more fully describe the manner of burning which I have had in practice for the last six years, and which I can therefore recommend with great confidence. The great object in brick-burning is to attain a sufficient heat to thoroughly burn the ware with as small a consumption of coal as possible; and with nearly an equal distribution of the heat over all parts, so that the whole of the ware, being subjected to the same temperature, may contract equally in bulk, and be of equal strength throughout. The advantage is also gained of burning in much less time than in the old kilns, which, on an average, took a week; and the management is so simplified that any man, even though not at all conversant with the manufacture, after he has seen one kiln burnt, will be able to manage another; and the last, though not least, advantage is, that of delivering up to us the waste heat at the ground level, or under the floor of the kiln, to be used in drying the green ware, or in partially burning the next kiln.

Hitherto the heat has been applied by a series of fire-places, or flues and openings round the kiln, each exposed to the influence of the atmosphere; and in boisterous weather it is very difficult to keep the heat at all regular, the consequence of which is the unequal burning we often see. The improvements sought by experimentalists have been the burning the goods equally, and, at the same time, more economically. These are obtained by the patent kilns, as improved by Mr. Robert Scrivener, of Shelton, in the Staffordshire Potteries. The plan is both simple and effective, and is as follows:—A furnace is constructed in the centre of the kiln, much below the floor level, and so built that the heat can be directed to any part of the kiln at the pleasure of the fireman. First, the heat is directed up a tube in the centre to the top of the oven or kiln, and, as there is no escape allowed to take place there, it is drawn down through the good goods of brick in connection with a chimney. Thus, all the caloric generated in the furnace in a state of use, and, being central, is equally diffused throughout the mass; but, towards the bottom, or over the exits, the ware would not be sufficiently burnt without reversing the order of firing. In order to meet this requirement, there is a series of flues under the bottom, upon which the goods are placed, with small regulators at the end of each; these regulators, when drawn back, allow the fire to pass under the bottom, and to rise up among the goods which are not sufficiently fired, and thus the burning is completed. By means of these regulators the heat may be obtained exactly the same throughout; there is, therefore, a greater degree of certainty in firing, and a considerable saving of fuel, with the entire consumption of the smoke. From the flue or draught being under command, so as to be allowed either to ascend or descend through the ware during the time of burning or cooling, the waste caloric can be economized and directed through the adjoining kiln in order to partially burn it, or be used in drying off the raw wares on flues or in chambers. I have found the saving of fuel in these kilns, over the common kiln, 50 per cent.; and to give an idea of the facility with which they can be worked, it is common for my men to fill the kiln, burn, cool, and discharge it in six days."—Chamberlain.

There are numerous machines in use for the manufacture of bricks. For the manufacture of perforated bricks, Mr. Beart's machine is the most generally employed. Mr. Chamberlain thus describes it:—"The most universally used die machine which has been extensively worked up to the present time is Mr. Beart's patent for perforated bricks. This gentleman, who is practically acquainted with these matters, in order to remedy the difficulties I have mentioned in expressing a mass of clay through a large aperture or die, hung a series of small tongues or cores, so as to form hollow or perforated bricks. By this means the clay was forced in its passage through the die into the corners, having the greatest amount of friction now in the centre. Still, the bricks came out rough at the edge with many clays, or with what is termed a jagged edge. The water die was afterwards applied to this machine, and the perforated bricks, now so commonly used in London, are the result. In Mr. Beart's machine, which is a pug-mill, the clay is taken after passing through the rolling-mill,"
and, being fed in at the top, is worked down by the knives. At the bottom are two horizontal clay-boxes, in which a plunger works backwards and forwards. As soon as it has reached the extremity of its stroke, or forced the clay of one box through the die, the other box receiving during this time its charge of clay from the pug-mill, the plunger returns and empties this box of clay through a die on the opposite side of the machine. The result is, that while a stream of clay is being forced out on one side of the machine, the clay on the opposite side is stationary, and can, therefore, be divided into a series of five or six bricks with the greatest correctness by hand. Some of these machines have both boxes on one side, and the plungers worked by cranks. This machine cannot make bricks unless the clay has previously passed through rollers, if coarse; for any thing at all rough, as stone or other hard substance, would hang in the tongues of the die. But the clay being afterwards pugged in the machine, is so thoroughly tempered and mixed, that the bricks, when made, cannot be otherwise than good, provided they are sufficiently fired. As to the utility of hollow or perforated bricks, that is a matter more for the consideration of the architect or builder than for the brick-maker. Perforated bricks are a fifth less in weight than solid ones, which is a matter of some importance in transit; but it takes considerably more power to force the clay through those dies than for solid brick-making. In the manufacture of perforated bricks, there is also a royalty or patent right to be paid to Mr. Beart."

87a

Mr. Chamberlain's own machine is in principle as follows (fig. 87a):—The clay is fed into a pug-mill, placed horizontally, which works and amalgamates it, and then forces it off through a mouth-piece or die of about 65 square inches, or about half an inch deeper, and half an inch longer than is required for the brick, of a form similar to a brick on edge, but with corners well rounded off, each corner forming a quarter of a 3-inch circle, for clay will pass smoothly through an aperture thus formed, but not through a keen angle. After the clay has escaped from the mill, it is seized by four rollers, covered with a porous fabric, (moleskin,) driven at a like surface speed from connection with the pug-mill. These rollers are two horizontal and two vertical ones, having a space of 45 inches between them; they take this larger stream of rough clay, and press or roll it into a squared block, of the exact size and shape of a brick edgewise, with beautiful sharp edges, for the clay has no friction, being drawn through by the rollers instead of forcing itself through, and is delivered in one unbroken stream. The rollers in this machine perform the functions of the die in one class of machinery, and of the mould in the other. They are, in fact, a die with rotating surfaces. By hanging a series of mandrels or cores between these rollers, or by merely changing the mouth-piece, we make hollow and perforated bricks, without any alteration in the machine.

Messes. Bradley and Craven, of Wakefield, have invented a very ingenious brick-making machine:—

It consists of a vertical pug-mill of a peculiar form, and greatly improved construction, into the upper part of which the clay is fed. In this part of the apparatus the clay undergoes a most perfect tempering and mixing, and, on reaching the bottom of the mill, thoroughly amalgamated, is forcibly pressed into the moulds of the form and size of brick required, which are arranged in the form of a circular revolving table.
As this table revolves, the piston-rods of the moulds ascend an incline plane, and gradually lift the bricks out of the moulds, whence they are taken from the machine by a boy, and placed on an endless band, which carries the bricks direct to the waller, thus effecting the saving of the floor room.

The speed of the several parts of the machine is so judiciously arranged, that the operations of puddling, moulding, and delivering proceed simultaneously in due order, the whole being easily driven by a steam engine of about six-horse power, which, at the ordinary rate of working, will make 12,000 bricks per day; or, with eight-horse power, from 15,000 to 18,000.

In consequence of the perfect amalgamation of the clay, and the great pressure to which it is subjected in the moulds, the bricks produced by this machine are perfect; and from the stiffness of the clay used, less water has to be evaporated in the drying, thus saving one-half the time required for hand-made bricks, and avoiding the risk of loss from bad weather.

A very ingenious and simple brick-making machine was constructed and patented by Mr. Roberts, of Falmouth, and it has been extensively worked by him in the parish of Mylor.

Fig. 89 shows a plan of machinery combined, according to Mr. Roberts's invention, and fig. 90 shows a side elevation, partly in section. \(a\) is a circular track, on which are fixed series of moulds, \(b\), at intervals, the form of moulds being according to the shape of bricks or tiles to be made. Each set of moulds is provided with movable bottoms, (one for each mould,) which are connected to the bar, \(c\), so that they may be all simultaneously lifted by the lever, \(d\).

In fig. 90, one set of the moulds and apparatus used therewith is shown, and the several sets of moulds (the positions of which are in the drawing, fig. 89) are similarly provided. \(e\) is a roller, which is moved round on the track, \(a\), by means of the frame, \(f\), which receives motion from a steam-engine or other power, by means of the shaft, \(g\), the cog-wheel, \(h\), and circular-toothed rack fixed on the frame, \(f\). The clay, or brick earth, is filled into the moulds, and the roller, \(e\), presses the same into the moulds as it rolls over them; \(i\) is a scraper which, following the roller, \(e\), removes any excess of clay or brick earth from the moulds; and \(j\) is a smaller roller, which acts as a balance, to prevent the cutter from rising; \(k\) is a pressing plate attached to the bar, \(c\), and is raised at the same time by the lever, \(d\). The roller, \(e\), in its further progress, passes over and presses down the plate, \(k\), which completes the pressure; \(e\) then passes on and presses down the lever, \(d\), by which all the movable bottoms of the moulds will be raised with the bricks or tiles theron. The whole of the pistons and bar, \(c\), are kept up by the stop, \(l\), which works by a spring, and is removed by the treadle, \(m\), as soon as the bricks or tiles are taken away; \(n\) are small rollers, fixed to the frame, \(o\), to which the cutter or scraper is attached.
For the analyses of the clays of which these and others are constructed, see Clay.

Stone Bricks.—These are manufactured at Neath, in Glamorganshire, and are very much used in the construction of copper furnaces at Swansea.

The materials of which the bricks are made are brought from a quarry in the neighborhood. They are very coarse, being subjected to a very rude crushing operation under an edge stone, and, from the size of the pieces, it is impossible to mould by hand. There are three qualities, which are mixed together with a little water, so as to give the mass coherence, and in this state it is compressed by the machine into a mould. The brick which results is treated in the ordinary way, but it resists a much greater heat than the Stourbridge clay brick, expands more by heat, and does not contract to its original dimensions.

The composition of the three materials is as follows:—

From Pendreyn. From Diana.
Silica 94:95 100:91:95
Alumina, with a trace of ox. iron 4:55 traces 8:95
Lime and magnesia traces traces

98:60 100:100:00

—Dr. Richardson: Knapp’s Technology.

In immediate connection with this subject, it appears that the following machine for raising bricks, mortar, &c, by M. Pierre Journet, described to the London Institution of Civil Engineers, merits attention. It is a machine for raising bricks and materials to pro-
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grease heights in the building of chimneys and other works. A strong frame on the ground contained the winch wheel, and on the second motion a notched wheel; on the scaffold frame above is a similar notched wheel, and round these two wheels an endless chain travels, made of flat links and cross pins, which are held by the notches in the wheels. The buckets for mortar, and hods for bricks, are hooked upon these transverse pins, and are raised, by the winch motion below, to the landing above; the bricks are removed by laborers, and empty buckets and hods hung to the descending chain, to be detached and filled below.

It appeared that a working rate of 15 feet in a minute for the chain to travel was a convenient rate for the men. One man turning the winch will raise—

<table>
<thead>
<tr>
<th>Feet</th>
<th>Bricks per minute</th>
<th>Bricks per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>90</td>
<td>5400</td>
</tr>
<tr>
<td>20</td>
<td>45</td>
<td>2700</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
<td>1800</td>
</tr>
<tr>
<td>40</td>
<td>22</td>
<td>1330</td>
</tr>
<tr>
<td>50</td>
<td>18</td>
<td>1050</td>
</tr>
<tr>
<td>60</td>
<td>15</td>
<td>900</td>
</tr>
</tbody>
</table>

As the work increases, the scaffold is elevated, and the chain lengthened, adding more hods.

The great advantages are, that the men are relieved from the labor of climbing ladders and risk of accidents, that the building is carried on quicker, and therefore at less cost. The plan was adopted with success at the large buildings at Albert Gate, Hyde Park, and at the new Houses of Parliament.

Steam power, of course, can be employed; and a great practical advantage arises from not encumbering the building with the weight of ladders, and materials collected on the scaffolding.

BROMINE. (Br. Atomic weight, 80. Density in liquid state, 2.97. Density of vapor by experiment, 3.39; calculation on supposition of the density of hydrogen being 0.092353.) One of the most active of the elements. It was discovered in 1826, by Balard, of Montpellier, in the bitters produced from the water of the Mediterranean. Bromine is a very interesting substance, and its discovery has had great influence on the progress of theoretical and applied chemistry. It is the only element, save mercury, which exists in the fluid state at ordinary temperatures. It is found not only in sea water, but in numerous saline springs. It also exists in combination with silver and chlorine in some Mexican and Chilian minerals.

Preparation 1. From bitters.—Chlorine gas is passed in for some time; this has the effect of combining with the metallic base of the bromide present, the bromine being, in consequence, liberated. When the bitters no longer increases in color, the operation is suspended, or chloride of bromine would be formed, and spoil the operation. The colored fluid is placed in a large globe, with a neck having a glass stopcock below like a tap funnel, the upper aperture being closed with a stopper. Ether is then added, the stopper replaced, and the whole well agitated. After a short repose, the ether rises to the surface retaining the bromine in solution. The stopper being removed to permit the entrance of air, the stopcock is opened, and the aqueous fluid is permitted to run out. As soon as the highly colored ethereal solution arrives at the aperture in the stopcock, the latter is shut; a quantity of solution of potash is then poured, by the upper aperture, into the globe, and the stopper is replaced. The whole is now to be agitated, by which means the bromine combines with the potash, forming a mixture of bromate of potash and bromide of potassium. The stopcock is again opened, and the aqueous fluid received into an evaporating vessel, boiled to dryness, and ignited. By this means the bromate of potash is all converted into bromide of potassium. The bromine may be procured from the bromide of potassium by distillation with peroxide of manganese and sulphuric acid. In this operation one equivalent of bromine, two equivalents of sulphuric acid, and one of peroxide of manganese, yield one equivalent of sulphate of manganese, one of sulphate of potash, and one of bromine; or, in symbols, KBr + 2MnO4 = KO, SO4 + MnO3, SO4 + Br. The reaction, in fact, takes place in two stages, but the ultimate result is as represented in the equation.

Preparation 2.—In some saline springs where bromine is present, accompanied by considerable quantities of salts of lime, &c., the brine may be evaporated to one-fourth, and, after repose, decanted or strained from the deposit. The mother liquid is to have sulphuric acid added, in order to precipitate most of the lime. The filtered fluid is then evaporated to dryness, redissolved in water, and filtered; by this means more sulphate of lime is got rid of. The fluid is then distilled with peroxide of manganese and hydrochloric acid. The only well-developed oxide of bromine is bromic acid, BrO3. Solutions of bromine in water may have their strength determined, even in presence of hydrochloric or hydrobromic acids, by means of a solution of turpentine in alcohol. One quarter of an equivalent of turpentine (C. G. W. 72 parts) decolorizes 80 parts or 1 equivalent of bromine.—C. G. W.

BRONZE. (Bronze, Fr.; Bronze, Germ.) A compound metal consisting of copper and tin, to which sometimes a little zinc and lead are added. There is some confusion
amongst continental writers about this alloy; they translate their bronze into the English brass.

See, for an example of this, "Dictionnaire des Arts et Manufactures." This has arisen from the carelessness of our own writers. Dr. Watson, "Chemical Essays," remarks: "It has been said that Queen Elizabeth left more brass ordinance at her death than she found iron on her accession to the throne. This must not be understood as if gun metal was made in her time of brass, for the term brass was sometimes used to denote copper; and sometimes a composition of iron, copper, and calamine was called brass; and we, at this day, commonly speak of brass cannon, though brass does not enter into the composition used for casting cannon."

Bronze is an alloy of copper and tin.
Brass is an alloy of copper and zinc.

In many instances, we have zinc, lead, &c., entering into the composition of alloys of copper and tin. However this may be, the alloy is called a bronze, if tin and copper are the chief constituents.

This alloy is much harder than copper, and was employed by the ancients to make swords, hatchets, &c., before the method of working iron was generally understood. The art of casting bronze statues may be traced to the most remote antiquity, but it was first brought to a certain degree of refinement by Theodorus and Koreus of Samos, about 700 years before the Christian era, to whom the invention of modelling is ascribed by Pliny. The ancients were well aware that by alloying copper with tin, a more fusible metal was obtained, that the process of casting was therefore rendered easier, and that the statue was harder and more durable. It was during the reign of Alexander that bronze statuary received its greatest extension, when the celebrated artist Lydippus succeeded, by new processes of moulding and melting, in multiplying groups of statues to such a degree that Pliny called them the mob of Alexander. Soon afterwards enormous bronze colossuses were made, to the height of towers, of which the isle of Rhodes possessed no less than one hundred. The Roman consul Mutianus found 3,000 bronze statues at Athens, 3,000 at Rhodes, as many at Olympia and at Delphi, although a great number had been previously carried off from the last town.

From the analyses of Mr. J. A. Phillips, we learn that most of the ancient coins were bronzes, the quantity of tin relatively to the copper varying slightly. The proportions of copper and tin in many of those coins are given below, the other ingredients being omitted:

<table>
<thead>
<tr>
<th>Copper</th>
<th>Tin</th>
</tr>
</thead>
<tbody>
<tr>
<td>A coin of Alexander the Great, 335 B.C.</td>
<td>86:72</td>
</tr>
<tr>
<td>&quot;</td>
<td>200 B.C.</td>
</tr>
<tr>
<td>Atheni</td>
<td>88:41</td>
</tr>
<tr>
<td>Ptolemy IX.</td>
<td>70 B.C.</td>
</tr>
<tr>
<td>Pompey</td>
<td>55 B.C.</td>
</tr>
<tr>
<td>the Aethia family</td>
<td>45 B.C.</td>
</tr>
<tr>
<td>Augustus and Agrippa</td>
<td>30 B.C.</td>
</tr>
</tbody>
</table>

The arms and cutting instruments of the ancients were composed of similar bronzes, as the following proportions, also selected from Mr. J. A. Phillips’s analyses, will show:

<table>
<thead>
<tr>
<th>Copper</th>
<th>Tin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roman sword blade, found in the Thames</td>
<td>85:70</td>
</tr>
<tr>
<td>&quot;</td>
<td>100:02</td>
</tr>
<tr>
<td>&quot; &quot;</td>
<td>91:39</td>
</tr>
<tr>
<td>Celtic</td>
<td>90:23</td>
</tr>
</tbody>
</table>

Layard brought from Assyria a considerable variety of bronze articles, many of them objects of ornament, but many evidently intended for use. Amongst others was a bronze foot, which was constructed for the purpose of support of some kind. This was submitted to the examination of Dr. Pery. It was then found that the bronze had been cast round a support of iron. By this means the appearance of considerable lightness was attained, while great strength was insured. This discovery proves, in a very satisfactory manner, that the metallurgists of Assyria were perfectly conversant with the use of iron, and that they employed it for the purpose of imparting strength to the less tenaceous metals which they employed in their art manufactures. This bronze, as analysed in the Metallurgical Laboratory of the Museum of Practical Geology, consists of copper 88:37, tin 11:23.

Examination has shown that all the bronze weapons of the Greeks and Romans were not only of the true composition for ensuring the greatest density in the alloy itself, but that these, by a process of hammering the cutting edges, were brought up to the greatest degree of hardness and tenacity.

Before 1342 "brass ordinance" (brass) was founded by foreigners. Stow says that John Owen began to found brass ordinance, and that he was the first Englishman who ever made that kind of artillery in England.

Bell foundling followed. Bell metal and other broken metal were allowed to be ex-
BRONZING.

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ported hitherto; but it being discovered that it was applied to found guns abroad, "brass, copper, latten, bell metal, pan metal, gun metal, and shinoff metal are prohibited to be exported."

Bronze has almost always been used for casting statues, basso relieves, and works which were to be exposed to atmospheric influences. In forming such statues, the alloy should be capable of flowing readily into all the parts of the mould, however intricate; it should be hard, in order to resist accidental blows, be proof against the influence of the weather, and be of such a nature as to acquire that greenish oxidized coat upon the surface, which is so much admired in the antique bronzes, called *patina antiqua*. The chemical composition of the bronze alloy is a matter, therefore, of the first moment. The brothers Keller, celebrated founders in the time of Louis XIV., whose *chefs-d'oeuvre* are well known, directed their attention towards this point, to which too little importance is attached at the present day. The statue of Desalx, in the Place Dauphine, and the column in the Place Vendome, are noted specimens of most defective workmanship from mismanagement of the alloys of which they are composed. On analyzing separately specimens taken from the base-reliefs of the pedestal of this column, from the shaft, and from the capital, it was found that the first contained only 6% per cent. of tin, and 94 of copper, the second much less, and the third only 0-21. It was therefore obvious that the founder, unskilful in the melting of bronze, had gone on progressively refining his alloy, by the exudation of the tin, till he had exhausted the copper, and that he had then worked up the refuse scorin in the upper part of the column. The cannon which the Government furnished him for casting the monument consisted of:

<table>
<thead>
<tr>
<th>Copper</th>
<th>Tin</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

89-360
10-040
0-102

0-498

100-000

For the following table we are indebted to Mr. Robert Mallet, C. B., whose investigations in this direction have been most extensive, and as accurate as they are extensive:

<table>
<thead>
<tr>
<th>Chemical Constitution</th>
<th>Composition by Weights</th>
<th>Atomic Weight</th>
<th>Specific Gravity</th>
<th>Porosity</th>
<th>Color of Fracture</th>
<th>Commercial Name</th>
<th>Commercial Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Cu+Sn</td>
<td>100-00</td>
<td>0-936</td>
<td>8-965</td>
<td>□</td>
<td>Tile red</td>
<td>Copper</td>
<td>Copper</td>
</tr>
<tr>
<td>10 Cu+Sn</td>
<td>84-29</td>
<td>15-71</td>
<td>3-82</td>
<td>III</td>
<td>Reddish yellow</td>
<td>Gun metal, &amp;c.</td>
<td>Ditto</td>
</tr>
<tr>
<td>3 Cu+Sn</td>
<td>82-81</td>
<td>17-19</td>
<td>3-456</td>
<td>II</td>
<td>Reddish yellow</td>
<td>Gun metal, &amp;c.</td>
<td>Ditto</td>
</tr>
<tr>
<td>4 Cu+Sn</td>
<td>81-30</td>
<td>18-90</td>
<td>3-117</td>
<td>V</td>
<td>Yellowish red</td>
<td>Gun metal, tempers best</td>
<td>Ditto</td>
</tr>
<tr>
<td>+Sn 75-7</td>
<td>74-27</td>
<td>15-03</td>
<td>3-873</td>
<td>IV</td>
<td>Yellowish red</td>
<td>Hard mill brasses, &amp;c.</td>
<td>Ditto</td>
</tr>
<tr>
<td>6 Cu+Sn</td>
<td>76-29</td>
<td>29-71</td>
<td>3-870</td>
<td>V</td>
<td>Blush red</td>
<td>Brittle</td>
<td>Brittle</td>
</tr>
<tr>
<td>1 Cu+Sn</td>
<td>72-69</td>
<td>27-39</td>
<td>3-975</td>
<td>VI</td>
<td>Blush red</td>
<td>Brittle</td>
<td>Brittle</td>
</tr>
<tr>
<td>8 Cu+Sn</td>
<td>66-21</td>
<td>34-78</td>
<td>3-900</td>
<td>VII</td>
<td>Ash grey</td>
<td>Brittle</td>
<td>Brittle</td>
</tr>
<tr>
<td>9 Cu+Sn</td>
<td>61-23</td>
<td>35-81</td>
<td>3-803</td>
<td>VIII</td>
<td>Dark grey</td>
<td>Brittle</td>
<td>Brittle</td>
</tr>
<tr>
<td>3 Cu+Sn</td>
<td>51-75</td>
<td>42-25</td>
<td>3-225</td>
<td>IX</td>
<td>Greyish white</td>
<td>Brittle</td>
<td>Brittle</td>
</tr>
<tr>
<td>11 Cu+Sn</td>
<td>44-29</td>
<td>56-95</td>
<td>3-800</td>
<td>X</td>
<td>Whiter still</td>
<td>Brittle</td>
<td>Brittle</td>
</tr>
<tr>
<td>12 Cu+Sn</td>
<td>22-15</td>
<td>73-83</td>
<td>3-049</td>
<td>XI</td>
<td>Ditto</td>
<td>Brittle</td>
<td>Brittle</td>
</tr>
<tr>
<td>8 Sn</td>
<td>0-00</td>
<td>100-00</td>
<td>0-000</td>
<td>XX</td>
<td>White</td>
<td>Metal of authors</td>
<td>Metal of authors</td>
</tr>
<tr>
<td>13 Cu+Sn</td>
<td>51-75</td>
<td>42-25</td>
<td>3-225</td>
<td>XII</td>
<td>Ditto</td>
<td>File, tough</td>
<td>File, tough</td>
</tr>
<tr>
<td>9 Cu+Sn</td>
<td>46-29</td>
<td>54-71</td>
<td>3-742</td>
<td>XIII</td>
<td>Ditto</td>
<td>File, soft and tough</td>
<td>File, soft and tough</td>
</tr>
<tr>
<td>15 Cu+Sn</td>
<td>49-25</td>
<td>50-75</td>
<td>3-742</td>
<td>XIV</td>
<td>Ditto</td>
<td>File, soft and tough</td>
<td>File, soft and tough</td>
</tr>
<tr>
<td>16 Sn</td>
<td>0-00</td>
<td>100-00</td>
<td>0-000</td>
<td>XV</td>
<td>White</td>
<td>Metal of authors</td>
<td>Metal of authors</td>
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</table>

In 1855, we imported, of Bronze, works of art, 21 cwt.; and of manufactures of bronze, or of metal bronzed or lacquered, 3,492 cwt.

BRONZING. The process for giving to metals, plaster, wood, or any other body, a bronze-like surface.

Various processes have been adopted for producing this effect.

When brass castings are to be bronzed, it is essential, in the first place, that they should be thoroughly cleansed from grease, and brightened either with the file or emery-paper, or by boiling in a strong lye and then scouring with fine sand and water.

Vinegar alone is sometimes employed to produce the green bronze color; sometimes dilute nitric acid, and often the mixture of ammonia, (*sal ammoniacus*). This latter salt and

* signifies earthy; o, coarse crystalline; r, fine crystalline; c, conchoideal; v, vitreous; v c, vitreous-conchoideal; t v, tumbler crystalline.

All these alloys are found occasionally in bells and specula with mixtures of Zn and Pb.
BRONZE POWDERS.

The best and most rapid bronzing liquid, which may be applied to copper, brass, iron, or to new bronze, with equal advantage, is a solution of the chloride of platinum (nitro-muriate of platinum) called chemical bronze; but it is expensive. With the chloride of platinum, almost any color can be produced, according to the degree of dilution, and the number of applications.

Some beautiful effects are produced upon bronze, and also upon iron castings, by treating them with dilute acids. The action here is scarcely to be described as bronzing; it is, in fact, merely developing the true color of the metal or alloy.

With the view of rendering the action of the bronzing liquid as uniform as possible, small articles are dipped; for larger articles, the bronzing liquid is dashed on plentifully with a linen rag. The dabling process is to prevent the occurrence of streaks, which might arise if the liquid was applied in straight strokes. When properly bronzed and washed, the work is usually black-leaded, to give it a polished appearance.

BRONZE POWDERS have been much used of late in the decorative painting of houses, &c. They are prepared of every shade, from that of bright gold to orange, dark copper, emerald green, &c. Pale gold is produced from an alloy of 144 of copper, and 24 of zinc; crimson metallic lustre—from copper: ditto, pale, copper and a very little zinc; green bronze, with a proportion of verdigris; another fine orange by 144 copper and 14 zinc; another ditto, 134 copper and 24 zinc: a beautiful pale gold from an alloy of the two metals in atomic proportions.

The alloy is laminated into very fine leaves with careful annealing, and these are levigated into impalpable powders along with a film of fine oil to prevent oxidization, and to favor the levigation.

On the subject of bronze powders and metallic leaves, Mr. Brandeis furnished to the New York Exhibition an account of his articles of manufacture:

Bronzes, or, more correctly, metallic powders resembling gold dust, were invented, according to my researches, in 1648, by a monk, at Furth, in Bavaria, named Theophrastus Alia Bombergensia. He took the scraps or cuttings of the metallic leaves then known as ‘Dutch leaf,’ and ground them with honey. This roughly made bronze powder was used for ornamenting parchments, capital letters in Bibles, choral books, &c.

As the consumption of metallic leaf increased, and the properties of alloys became better known, leaves of different colors were produced, and from the scraps a variety of powders or bronzes.

At Furth, bronze powders are largely made for Europe, and with little change or improvement. There are four sorts of Dutch leaf:

Common leaf, soft, and of a reddish cast, composed of 25 or 30 per cent. of zinc to 75 or 70 per cent. of copper.

French leaf contains more zinc, is harder, less ductile, and has a purer yellow color.

Florence leaf has a larger proportion of zinc, and is of a greenish gold color; and lastly—

White leaf, composed of tin. The more zinc these alloys contain, the harder, the more brittle, and more difficult are they to work into perfect leaves. The manner of beating is similar to the mode for producing gold leaves.

The scraps, cuttings, and fragments of these leaves are the materials for the German bronze powders. First brushied through a sieve and ground with gum water on marble slabs for six hours, the gum washed out, the powders sorted, dried, and a coating of grease given to make them appear more brilliant, and to protect them from oxidation. Varieties of color, such as orange, &c., are produced by a film of suboxide upon the surface of the particles.

The price of bronze powders depends upon the demand, and the supply of the waste material of the metal leaves, and prices change accordingly.

Mosses, Brandeis patent their process, and in place of being dependent upon uncertain supplies of metal and unknown composition, they take the metals at once in a state of purity, (say copper by voltaic precipitation;) it is alloyed with zinc, cast into ingots, rolled into ribands, cut, annealed, and rolled until the metal is thin and leaf-like; then it is taken to a steam-mill, and ground. The bronze powder is washed out and dried, then introduced into an air-tight room, with an arrangement of boxes; the air of the chamber is set in violent motion by bellows, and the powder diffused throughout; the bronze powders are deposited, the finest in the upper boxes, and the coarser powders below. When settled, mineral varnish is introduced; the boxes, fitted with tight lids, are made to revolve, and the particles are thus rapidly coated, and the highest metallic brilliancy imparted. Different shades of color, pink, crimson, &c., are produced by submitting the powder to heat and oxidation before the rapid revolutions of the varnishing boxes.

The quantity thus produced by one firm, with three steam-engines at work, enables the finished bronze powders to be produced at a rate about equal to the price the German manufacturer has to pay for his materials—the cuttings and scraps of leaves. Hence, for
BROWN IRON ORE.

the purposes of trade and art, a large exportation of bronze powders takes place from America to Europe, South America, and China. The bronze powders are largely used in japanning, bronzing tin and iron goods, ornamental works of paper, wood, oil-cloth, leather, &c.; while sign-boards and the decoration of public buildings have effective metallic brilliant surfaces of beauty and durability. In fact, for ornamental decorations, the demand steadily increases.

In Holland and Germany the subject has been examined, with the view of ascertaining the effect of chemical composition.

De Heer E. R. König has lately given a table of the analyses of the best European samples of bronze powders and leaves, (Volkfright:—)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1.</td>
<td>Light yellow</td>
<td></td>
<td></td>
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<tr>
<td>2.</td>
<td>Gold yellow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Messing yellow, or brass copper red-yelow color</td>
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<tr>
<td>4.</td>
<td>Copper bronze orange</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5.</td>
<td>Copper red, high shade of purple color</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Purple violet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Light green</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Tin white or leaden gray</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Per cent.</td>
<td>Per cent.</td>
<td>Per cent.</td>
<td>Per cent.</td>
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</tr>
<tr>
<td>1.</td>
<td>82-38</td>
<td>16-09</td>
<td>0-16</td>
<td>0</td>
</tr>
<tr>
<td>2.</td>
<td>84-30</td>
<td>15-30</td>
<td>0-07</td>
<td>0</td>
</tr>
<tr>
<td>3.</td>
<td>90-</td>
<td>9-61</td>
<td>0-20</td>
<td>0</td>
</tr>
<tr>
<td>4.</td>
<td>98-93</td>
<td>0-75</td>
<td>0-08</td>
<td>0</td>
</tr>
<tr>
<td>5.</td>
<td>99-90</td>
<td>0-00</td>
<td>trace.</td>
<td>0</td>
</tr>
<tr>
<td>6.</td>
<td>98-22</td>
<td>0-5</td>
<td>0-30</td>
<td>trace.</td>
</tr>
<tr>
<td>7.</td>
<td>84-82</td>
<td>15-02</td>
<td>0-03</td>
<td>trace.</td>
</tr>
<tr>
<td>8.</td>
<td>0-00</td>
<td>2-50</td>
<td>0-56</td>
<td>97-46</td>
</tr>
</tbody>
</table>

Our imports in 1856 of Bronze Powders were valued at £4,737, according to the Custom House computation.

BROWN COAL is of a brownish-black color, and presents, in some cases, the texture of wood, when it is called Lignite; but, in some varieties, all organic structure has disappeared, and it is then called pitch coal, from its strong resemblance to true coal.

The beds of brown coal are generally of small extent, and are of later date than the true carboniferous strata, belonging to the Tertiary period.

Brown coal is worked in Saxony and in countries where there is an absence of true carboniferous deposits. It burns with an emphysematic color, and generally contains more pyrites than ordinary coal.

At Steigerberg, in Southern Styria, brown coal occurs in the form of a basin; and has been opened out through a distance of more than two miles. The coal, from 8 to 16 feet thick, is of good quality. It contains 9 to 14 per cent. of water, and leaves from 5 to 12 per cent. of ash after combustion.

The following is an analysis of a variety from Oregon: volatile matter, 49-5; fixed carbon, 42-9; ash, 2-7; water, 4-9 = 100-0.

A variety of brown coal, called the paper-coal of Rott, near Bonn, and of Erpel on the Rhine, contains numerous remains of freshwater fishes, Lenechistes papyraceus; and of frogs, Palaeophrygnos grandipes. The ashes of this coal are, also, rich in infusorial remains.

For an account of the brown coals of this country, see Lignite and Boghead Coal.—

H. W. B.

BROWN IRON ORE (or Limonite) is one of the most important ores of iron, and, at the same time, one of the most abundant as well as most widely diffused. It never occurs crystallized, but usually in stalactitic, botryoidal, and mammillated forms, with a fibrous structure, a silky lustre, and often a semi-metallic appearance; it also occurs massive and sometimes earthy. In color it is of various shades of brown, generally dark, never bright. It affords a brownish-yellow streak, which distinguishes it from other ores of the same metal. It dissolves in warm nitro-muriatic acid, and in a matrass gives off water. Before the blowpipe it blackens and fuses, when in thin splinters; with borax, it gives an iron reaction. H = 5 to 5-5; specific gravity = 3-6 to 4. Brown iron ore is a hydrated peroxide of iron, composed of peroxide of iron, 58-5, and water, 14-4 = 100-0; but it frequently contains small percentages of silica, alumina, &c.

The principal varieties of this ore are brown hematite, comprising the compact and mammillary varieties, scaly and ochral brown iron ore, yellow ochre constituting the decomposed earthy varieties, which are often soft, like chalk. Bog iron ore and clay iron stone are sometimes classed under this head, but it appears to us, especially as it regards the latter, improperly. The hydrated oxides of Northamptonshire and Bedfordshire may with propriety be called brown iron ore.

Brown iron ore is found in Cornwall, in the carboniferous limestone at Clifton, near Bristol, and in the Forest of Dean; in Shetland, Carlith, Bohemia, Siegen near Bonn, Villa Rica in the Brazil, and Peru.

Brown Hematite occurs at Talcheer, in the Bengal coal-bearing strata, which are probably of Permian age. It is smelted with the charcoal made on the spot, and produces iron
of excellent quality. According to the calculations of Professor Oldham, it takes 2½ tons of charcoal to produce 1 ton of iron.—H. W. B. See Iron.

**BRUCINE.** \((\text{C}_6\text{H}_13\text{NO}_4) \); syn. Caninarine, Vonicine. A very bitter and poisonous alkaloid accompanying strychnine in *Nux vomica* and in the false angusture bark, *Liruca antisyphilitica.*

**BRYLE or BROIL.** A mining term. The loose matters found in a ledge near the surface of the earth; probably a corruption of Bruhuel, (which see.)

**BRUSH WHEELS.** In light machinery, wheels are sometimes made to turn each other by means of axles fixed in their circumference; these are called brush wheels. The term is sometimes applied to wheels which move by their friction only.

**BUCKING.** A mining term. Bruising of the ore. A bucking iron is a flat iron fixed on a handle, with which the ore is crushed; and a bucking plate is an iron plate on which the ore is placed to be crushed.

**BUCKTHORN.** \((\text{Rhamnus catharticus})

This plant is a native of England; it grows to the height of from 15 to 20 feet; its flowers are greenish-colored, and its berries four-seeded. It is the fruit of this plant which is sold under the name of French berries. The juice of these, when in an unripe state, has the color of saffron; when ripe, and mixed with alum, it forms the sap-green of the painters; and in a very ripe state, the berries afford a purple color. The bark also yields a fine yellow dye.

**BUCKWHEAT.** \((\text{Fagopyrum esculentum})

The common buckwheat \((\text{Fagopyrum esculentum})

from *poly*, many, and *goua*, a nuce, in reference to its numerous joints) is cultivated for feeding pleasaants and other game; and is now being largely used in France and in this country in distilleries.

4. In France, besides being used for feeding fowls, pigs, &c., it is given to horses; and it is said that a bushel of its grains goes further than two bushels of oats, and, if mixed with four times its bulk of bran, will be full feeding for any horse for a week. Its hulls, or shades, is said to be more nourishing than that of clove, and its beautiful pink or reddish blossoms form a rich repast for bees."—Launson.

It has been stated that the leaves of the common buckwheat \((\text{Fagopyrum esculentum})

yield, by fermentation, Indigo blue. On examining this plant, its purpose of ascertainning whether this statement was correct, Schueck was unable to obtain a tincture of that coloring matter by means of extract fixed in their circumference; those are a quantity of a yellow coloring matter, which may very easily be obtained from it. This coloring matter crystallizes in small primrose-yellow needles. It is very little soluble in cold water, but soluble in boiling water, and still more soluble in alcohol. Muriatic and sulphuric acid change its color to a deep orange, the color disappearing on the addition of a large quantity of water. It dissolves easily in caustic alkalis, forming solutions of a beautiful deep yellow color, from which it is easily deposited in crystalline needles on exposing an excess of acid. It is, however, decomposed when its solution in alkali is exposed for some time to the air, being thereby converted into a yellowish-brown amorphous substance, resembling gum. Its compound with oxide of lead has a bright yellow color, similar to that of chrome of lead. The compounds with the oxides of tin are of a pale but bright yellow color. On adding protosulfate of iron to the watery solution, the latter becomes greenish, and, on exposure to the air, acquires a dark green color, and appears almost opaque. The watery solution imparts to printed calico, colors, some of which exhibit considerable liveness. Silk and wool do not, however, acquire any color when immersed in the boiling watery solution, unless they have previously been prepared with some mordant. The composition of this substance in 100 parts is as follows:—carbon, 50.00; hydrogen, 3.53; oxygen, 44.43. Its formula is probably \(\text{C}_6\text{H}_{13}\text{O}_{5}\text{N}^+\text{O}^-\). It appears to be identical with *rutin*, the yellow coloring matter contained in the *Ruta graveolens*, or common rue, and in eupers; and with *Hirsinthin*, a substance derived from the leaves of the common holly. From 1,000 parts of fresh buckwheat leaves, a little more than 1 part of the coloring matter may be obtained. As the seed of the plant is the only part at present employed, it might be of advantage to collect and dry the leaves, to be used as a dyeing material.—E. S.

**The Tartarian Buckwheat.** \((\text{Fagopyrum Tartarium})

This plant was introduced to the Royal Gardens at Kew by Mr. John Blake, in 1776. Authentic information as to its properties as a dye-yielding plant was only received at a comparatively recent period, from missionaries resident in China, where it has always been cultivated for its coloring matter. In Europe, attention was first directed to its growth by M. Delile, of the Jardin du Roi at Montpellier, who, in 1835, obtained seeds from the Baron Fischer, Director of the Imperial Gardens at St. Petersburg. It has since that time become sufficiently valuable to render its cultivation a dye drug of sufficient importance. The Japanese are said to extract blue dyes from *Polygonum Chinensis*, *P. barbatum*, and the common roadside weed, *P. aviculare.—Launson.*
BUDDLING. A mining term. The process of separating the metalliferous ores from the earthy matters with which they are associated, by means of an inclined hatch, called a 
bubble, over which water flows. It is indeed but an arrangement for availing ourselves of 
the action of flowing water to separate the lighter from the heavier particles of matter.

BUHL. Buhl-work consists of inlaid veneers, and differs from marquetry in being confined 

to decorative scroll-work, frequently in metal, while the latter is more commonly used for 
the representation of flowers and foliage. Boule, or Buhl, was a celebrated cabinet-
maker in France, who was born in 1642, and died in 1732. He was appointed " Tapisier 
tre du Roi," and he gave his name to this peculiar process of inlaying wood with either 
wood or metal. See MARQUETRY.

BUHR-STONE, mineralogically, is a cellular flinty quartz rock, constituting one of the 
jasper varieties of the quartz family. A celebrated grit-stone, much used in France and 
other parts of the continent for grist-mills. Those of La Ferté-sous-Jonarre (Seine et 
Maine) are regarded as superior to all others. In consequence of the necessity for carefully 
placing these stones together, they are naturally expensive; yet the demand for buhr-stones 
continues great.

BURLUSH, or TALL CLUB. (Scirpus lacustris; Celtic, cir, rushes.) The bulrush, 
belonging to the natural order of Cyperaceae, grows naturally on alluvial soils which are 
ocasionally covered with fresh water. It is much used by coopers for putting between the 
stakes of barrels, and by chair-makers. Many other plants belonging to this order are employed 
for economical purposes, such as forming seats, ropes, mats, and fancy basket-work, 
also for thatching houses. In 1856, we imported 562 tons.

BURGUNDY PITCH. Burgundy pitch, when genuine, is made by melting frank-
ence (Alsóde récina) in water, and straining it through a coarse cloth. The substance 
usually sold as Burgundy pitch is, however, common resin, incorporated with water, 
and colored with palm oil. In some cases American turpentine is employed. See PITCH and 
TAR.

BURNING HOUSE. A miner's term. In Cornwall the kiln or oven in which the tin 
and other ores are placed to sublimate the volatile constituents, sulphur, and arsenic, is so called.

BURROW. A miner's term for a heap of rubbish.

BUTT. A measure for wine, &c., containing 2 hogsheads, or 129 gallons.

BUTYLAMINE (CTH1N.) A volatile organic base, homologous with methylamine. It 
is found in the more volatile portion of bone oil. It may be prepared artificially by pro-
cesses analogous to those employed for methylamine, aniline, &c., substituting the 
butylc cyanate, urea, or iodide, for those of methyle and amyle.—C. G. W.

CABLE. We have avoided all relating to the general history and application of chain 
cables, but in connection with the following particulars, obtained from Brown, Lenox, and 
Co.'s chain works at Millwall, we must admit the important part performed by this house 
in the improvement of this manufacture. The following remarks refer to chain cables for the 
Royal Navy, messenger and mooring chains for the Trinity Corporation, and ship cables for merchant service, showing the practice in 1858.

After selecting the best iron, cutting it off into required lengths, and heating it, the links 
for chain cables may be bended at the rate of about 60 per minute, by machinery at Lenox's 
works in Wales, worked by water power,—the welding of the links, in all cases, being 
effected by hand labor.

In the practice with the new bending machine at New bridge Works, Pont-y-Prid, Glamorgan-
shire, it is as follows:—When the iron is cut to the requisite length for links, from 20 
to 90 pieces, according to size, are put into the furnace, and, when heated, are placed 
separately on the bending mandrel a. (fig. 91) the machine is set in motion, and one revolu-
tion forms a link which is pinched off the mandrel by a small crowbar, and another piece 
of iron applied, and so on, until from 40 to 60 links are formed in a minute.

The bending machine is connected with a water-wheel, or other power, by an ordinary 
coupling clutch, or box, which a lever throws into and out of gear at pleasure.

There is a stub or knob of iron on the mandrel under which the point of the piece of 
iron to be bent is fixed; the mandrel being oval, or of the inside shape of the link, when 
turned, is followed by the roller above, and this, pressing upon the piece of iron, forms it to 
the shape of the mandrel.

A B C (fig. 91) are standards, b, connecting rod, c, crank for lifting, f f, the roller for 
pressing sides of links, c, mandrel, h, mandrel spindle, i, wheel for mandrel spindle, j, 
plunger or main spindle, k, crank spindle.

The form of the link, after being bended into shape, (fig. 91), is shown with the two slant-
cut surfaces of the ends to be welded together and hammed into form.

For short lengths of chain, the bending may be effected by hand; in this case the pro-
cess is simple:—A sufficient length of the best iron is cut off, and, while hot, is partially bent by the workman over an iron ring, one end of the bar resting on the ground; the bend is finished upon the anvil; one entire length of the link is thus formed. The two slanting cut ends are made to approach each other; heated to a high temperature, the expert workman, by a peculiar blow, detaches the scale of oxide, and instantly presses both surfaces together; two men then, by repeated blows, effect the welding junction, and thus the link is formed.

The shape of the link, after due consideration of the advantages of particular patterns, seems to resolve itself into the decided preference for a link of parallel sides, unchanged in form from the round of the iron employed, while the ends may be reduced somewhat flattened, and increased in breadth. The links thus in contact have the pressure sustained by a greater breadth of surface, and compression can scarcely alter the form.

The length of a good link may be of round iron 6 diameters in length of link. (See fig. 92.) A a and from b to 37 to 4 diameters of the iron rod employed, and 17 to 2 diameters inside.

The stud, staple, or cross-bit is of cast-iron, and is placed across; its use is to prevent the sides from collapsing by extension of the chain; in fact, to keep up a succession of joints, and prevent the chain from becoming a rigid bar of metal.

The stud or cross-piece shown at c is of cast-iron, with dates and marks upon the surface. It is cast with a hollow bearing, having a curve to receive the round iron of the link; its shoulders, or feathering, enables the workman to insert it readily, and a few blows upon the yielding iron give the requisite grip, and all proper service only tends more firmly to keep it in position.

In all cases, this cross-piece has been of cast-iron. Wrought iron was tried, but found to be too expensive. Malleable iron has been patented, but it is a question whether it can supersede common foundry iron, from the cheapness and facility of the latter.

The cables are proved and tested by regulated strains brought to bear continuously up to the proof strain, and then even up to the ultimate destruction of some of the links, if the final strength or opposition to resistance is required to be known. The proof of cable should be 600 lbs. for each circle of iron 4 of an inch in diameter.

The chain is attached at one end horizontally to a hydraulic press, the other end to the enormous head of a bent iron lever, whose power is multiplied by second and third iron levers, all working upon knife edges, and to the last lever a scale-pan is attached; 1 lb. being here placed as equivalent to a strain of 2,240 lbs. upon the bar or chain that is being tested. This machine of Brown, Lenox, and Co., Millwall, is more powerful than that used in the Royal Dockyard. The proving machine, invented by Captain Brown in 1813, was a great step towards the production of confidence.

In practice, length after length is tried up to the proof required; when the tension is to be exerted to the utmost, a few links are taken: In such experiments, it is usual for one
CABLE. 221

link alone to give way, and the strength of the cable itself is uninjured by testing to find its ultimate strength.

Perfection of practice is found when the link and the stay yield together; in the largest chain cables ever produced, such were the due proportions and symmetry of form affording equality of resistance, that the cross-piece split or broke at the time the link fractured and opened.

To measure these chains, or be near them when under such tension, is not without danger. The cable, on being struck, rings out with strange shrill sound, a link may suddenly snap, the chain lashes about, and the fragments fly to a great distance, penetrating the factory roof at times, and, at the moment of fracture, the link becomes very hot.

The cables are usually told off into lengths. The Government length is 121 fathoms; for the merchant service the length is 15 fathoms; as explained, these lengths are united by shackles. In the merchant service cables, larger links are placed at each extremity for the anchor shackle to pass through; but in the Royal Navy cables each length is alike provided with large links; thus, then, at any time, any end of any length may be placed to the anchor stock. See figs. 92, 93.

To obviate evils from the twisting of the chain cable, swivels are inserted: in the Government cables, a swivel is inserted in the middle of every other length; for the merchant service there does not appear to be any precise rule. Sometimes one, two, or more swivels may be in 100 fathoms; and in cheap chains, bought and judged by weight and figures, no swivel whatever exists in the cable.

The effect of such twisting, or torsion, is to form a kink, and give powerful lateral pressure upon the link; the stud or cross-piece is forced out, and the link itself may yield at the moment at any flaw or imperfection of welding.

The mooring swivel is that by which a ship can ride with two anchors down at the same time, and two bridges on board the ship. The mooring swivel, being equal in strength to the two cables, is over the bow, and enables the ship to swivel round her anchors without fouling hawse; in any direction the ship can swing round this swivel or point, leaving her anchors undisturbed, whereas, by two cables out, without this, she would require great care to prevent them from fouling, and even being lost. This is an essential advantage of chain over hemp.

The splicing shackle is to unite or splice a hempen cable to be used on board ship, attached to the chain cable, which lies on the ground or bottom, so that the vessel rides lightly at her anchor, while the iron chain cable preserves the hempen cable from being destroyed by the rocky bottom, and the ship has the light hemp cable rendered buoyant by the water, which lifts portions of the chain cable by the motions of the vessel; and thus, the ship is relieved from weight and the anchor from jerks.

The splicing shackle, on the Hon. George Elliott's plan, is shown above, (fig. 93.) The rope is served round an iron thimble, a, on the shackle, b, with end links, and enlarged links without stay-pins, c, d, leading to the anchor, while the hempen cable, a, goes to the ship.

In the Royal Navy 4 cables are employed to moor the ships, two being end to end. When ships lay long on certain shores, the pin or fastening often gets loose by the constant tamping and vibrations of the chain cable on the rocky or shingly bottom. Men-of-war at some stations suffered severely in this way, and the commander at Malta had reason to represent it as a very serious matter. Mr. Lenox's plan for securing the bolts and pins is now made a point of contract to be adopted in all fastenings for the Royal Navy.

Simple as it would seem to devise a plan, yet it was years before all the difficulties could be surmounted. This arrangement may be understood by reference to the figure of a
shackle with links, (fig. 94;) at E is seen the aperture at right angles to the bolt, F, (of oval iron,) through this channel, cut through the shackle and the bolt, a tapering but not quite cylindrical steel pin fits exactly, but does not quite proceed through the iron; it is shown at g g. Various plans used to be resorted to before this final preference; for the steel pins, of whatever form, got loose by repeated tapping on the rocky bottom, or the links upon each other. Mr. Lenox succeeded in cutting the cavity at x of the form of a hollow cone, and to complete the fastening, a pellet or cylinder of lead that will just allow insertion at x is driven, and then, by repeated blows, the lead is made to fill up the cavity, the superfluous quantity of lead being cut off by the hammer at x. To release the bolt, it is only necessary to find the small space at the small end of the steel pin, to insert a punch, and then, with a few blows, the steel pin g g is driven out of its conical bearing, and its flat top and cutting edges enable it to emerge again at x. Being forced out, the bolt F is taken out, and the chain severed, if required; the aperture at x can be cleared of its lead by a proper cutting-out tool, and the steel pin replaced to make all fast.

This operation can be effected on the darkest night; the sailor can sever the chain cable, and thus, when one vessel is driving down upon another, more chain may be attached, or the cable severed, and no harm done; while with hempen cable it might be found more difficult, and even impossible, to cut them in time.

All the principles involved, and perfection of practice, in making chains and chain cables, have recently been deeply considered and fully verified by the firm of Brown, Lenox, and Co., Millwall, who, for the purpose of obtaining comparative results up to the greatest links required for the “Leviathan,” selected iron of the same identical quality and worked it into rods, links, and chains. The progression of resistance to increased strains, by increase of mass of iron, with all the influences of variation of make, flaws in the material, and other circumstances inseparable from practice, were thus matters of critical experiment.

Commencing with 4-inch chain, and trying 4 links of small chains up to 25, being the largest diameter of round iron for the greatest cable links ever hitherto made, being those for the sheet anchor of the “Leviathan,” taking the breaking strains, and reducing all the links to the proportion borne upon a ¼ of an inch in diameter, the minimum breaking force was 792-25 lbs., and the maximum 1052-8 lbs.

Sometimes the fracture was found to be dependent upon flaws, sometimes from overheating, or unequal heating, and other practical causes; but the whole series of experiments was important and interesting.

The iron lengths to the intense strains employed, long before fracture. The comparison of actual extension, while under enormous force at ordinary temperatures, was ascertained by the following impressive experiments:—

The “Leviathan” second-size cable of 25 diameter of iron employed in the links. Three links measured 35½ inches by strain of 10 tons, (of course, it requires power to extend them fairly.)

At 50 tons — — — stretched ½ of an inch.
   “ 85 ” — — — “ 11 “
   “ 110 ” — — — “ 14 “
   “ 140 ” — — — “ 17 “
   “ 150 ” — — — “ 18 “
   “ 160 ” — — — “ 19 “
   “ 170 ” — — — “ 20 “
   And broke “ 180 “

A few links of the best bow anchor cable of the “Leviathan” taken, proved, and destroyed.

Three links measured at 15 tons 39 inches.

At 75 tons — — — stretched ½ of an inch.
   “ 125 ” — — — “ 15 “
   “ 160 ” — — — “ 3 “
   “ 170 ” — — — “ 3½ “
   “ 180 ” — — — “ 4 “
   “ 190 ” — — — “ 4½ “
   “ 200 ” — — — “ 5½ “
   It bore “ 217 “
   And broke “ 218 “
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CACAO. The Theobroma Cacao (or Food of the Gods, as Linnaeus named the tree) is a native of the West Indies and of continental America. Its seeds, (Theob. Cacao,) when torrefied, and with various additions (sugar, and usually either cinnamon or vanilla) made into a paste, constitute Chocolate, (chocolate,) which furnishes a very nourishing beverage, void of the injurious properties ascribed to both tea and coffee; but which, on account of the contained oil, is apt to disagree with dyspeptics. Cocoa is another preparation of these seeds. It is said to be made from the fragments of the seed-coats, mixed with portions of the kernels. —Pereira. See Chocolate.

CAIRNGORM, or CAIRNGORM is the name generally applied to the more pellicul and pale-colored varieties of smoky quartz, with a tint resembling that of sherry or amber. It is so called from the district Cairngorm, or the "Blue Mountain," in the south-west of Banff, where these crystals are frequently found. When of a good color, this crystal is made into ornaments, and used for jewellery; indeed, so great a favorite is the Cairngorm with the people of Scotland, that brooches, pins, bracelets, and a variety of ornaments, are made with this stone, for use by all classes.

CALAMANDER. A wood, the produce of Ceylon. See Coromandel.

CALAMINE. A native carbonate of zinc. (See Zinc.) The term Calamine, or Lapis calaminaris, has been applied to this ore of zinc since the days of the Arabian alchemists. It is so used now by Brook and Miller, by Greg and Lettsom, and others; yet we find Dana defining calamine to be the hydrous silicate of zinc, —another example of the sad want of system, and indeed of agreement, among mineralogists.

CALCAREOUS EARTH (Terre calcaire, Fr.; Kalkerde, Germ.) commonly denotes lime, in any form; but, properly speaking, it is pure lime. This term is frequently applied to marl, and to earths containing a considerable quantity of lime.

CALCAREOUS SPAR. Crystalline native carbonate of lime, of which there are many varieties. Carbonic acid 44-0, lime 50-0, may be regarded as the usual composition of calc spar; it often contains impurities, upon which depend the colors assumed by the crystal. The carbonates of lime are extensively distributed in nature, as marbles, chalk, and crystalline minerals.

CALCAREOUS TUF A. This term is applied to varieties of carbonate of lime, formed by the evaporation of water containing that mineral in solution. It is formed in fissures and caves in limestone rocks, about the borders of lakes, and near springs, the waters of which are impregnated with lime. In the latter cases it is frequently deposited upon shells, moss, and other plants, which it covers with a calcareous crust, producing frequently a perfect representation in stone of the substance so enclosed.

CALCEDONY. See Chalcedony.

CALCINATION. (From Calcine.) The operation of expelling from a substance, by heat, either water, or volatile matter combined with it. Thus, the process of burning lime, to expel the carbonic acid, is one of calcination. The result of exposing the carbonate of magnesia to heat, and the removal of its carbonic acid, is the production of encaUned magnesia. This term was, by the earlier chemists, applied only when the substance exposed to heat was reduced to a calcin or to a friable powder, this being frequently the oxide of a metal. It is now, however, used when any body is subjected even to a process of roasting.

CALCIUM. (Equivalent 20.) The metal contained in the oxide well known as lime. It was first obtained by Davy, in 1808, by the electrolysis of the hydrate, carbonate, chlorite, or nitrate of lime. Matthessen obtains it by heating; in a porcelain crucible, a mixture of two equivalents of chloride of calcium, with one equivalent of chloride of strontium, and nitrate of ammonia, until the latter is volatilized. The current from six cells of Bunsen's battery is then sent through the mixture by a charcoal pole of as large size as possible, and a piece of iron piano-forte wire (No. 6) not more than two lines in length, which is united with the negative pole of the battery by means of a stronger wire reaching close to the surface. A small crust is to be formed round the wire at the surface. To collect the small globules deposited on the wire, the latter must be taken out every two or three minutes, together with the crust. The globules are crushed in a mortar, and the flattened granules are then picked out. Calcium is a brilliant pale yellow metal, malleable and ductile. See Lime.

CALICO PRINTING is the art of producing a pattern on cotton cloth, by printing in colors, or mordants, which become colors, when subsequently dyed. Calico derives its name from Calicut, a town in India, formerly celebrated for its manufactures of cotton cloth, and where calico was also extensively printed. Other fabrics than cotton are now printed by similar means, viz.: linen, silk, wool, and mixtures of wool and cotton. Linen was formerly the principal fabric printed, but since modern improvements have produced cotton cloth at comparatively cheap rate, linen fabrics are now sparingly used for printing, and then principally for handkerchiefs, linen cloth not producing such beautiful colors, in consequence of the small affinity of flax for mordants, or coloring matters. Silk printing, also,
is chiefly confined to handkerchiefs, but the printing of woollen fabrics or mousseline de
linens is an important branch of the art.

The first step in calico printing is to remove the fibrous down from the surface of
the cloth, which is done by passing the piece rapidly through a flame of gas, or over a red-hot
semicircular plate. The latter method will be found described under the head of BLEACH-
ING; the former is performed as follows:—Fig. 95 is a vertical section of the gas-singeing
apparatus. Its diameter is such as to admit of pieces of the greatest width. The pipe a
runs along from end to end under the machine, and is supplied with ordinary gas; the pipes
b n are branched into this, being five in number on each side. Connected with these
branches are the pipes, c c, which are perforated with fine holes, at distances of about ½
of an inch; the pipes b n are furnished with taps, a a. Above the tubes c c are the pipes, p n,
which are cut open at the bottom along the length, and communicate by the branch pipes,
p e, with the large pipe, e, which is exhausted by a fan. Two pairs of cylinders, e c, of
wood, covered with fustian, turn on their axes in the direction of the arrows, and draw
through them the pieces d d with a velocity of about 4 feet per second. The pair of rollers,
a e, to the right, are moved by a belt and pulley; the other pair is moved by belts which
embrace the under roller of each pair. n n are brushes, in pairs, which remove the loose
down. The rubber, r r, of wood, covered with fustian, serves to extinguish any sparks that
might be drawn on with the cloth. In using this machine, the two rows of gas are lighted,
and the size of flame regulated by the tape till it burns blue, and in one continuous line of
fire; the drawing rollers are then made to revolve, and the end of the first piece being laid
between the left rollers, is drawn through by means of a narrow piece of list fastened to it;
the end of the piece once through the right rollers, the operation proceeds rapidly, the
pieces, of course, being stitched end to end.

This gas-singeing apparatus has the effect of making cloth appear thinner than it really
is, in consequence of the flame passing through the fibres, and not merely on the surface.
It is, therefore, not so much used as the hot plate. In France and Germany a machine
called the toilerass is used, and which is very similar to the shearing machine used in the
manufacture of woollen cloth. (See Woolen MANUFACTURE.) A series of knives, running
spirally round a roller, shave off the down by the roller revolving on its axis as the cloth
passes underneath. This machine makes the cloth smoother and more free from flaws or
lumps than either of the other machines, but is not yet used in England.

The bleaching requisite for printing cloths is of much superior nature to that sufficient
for calico intended to be sold in the white state. It is sufficient for the latter to be white
enough to please the eye, a result easily obtained by chlorine treatment after a compara-
tively mild alkaline boiling; but the former must be so well boiled with lime and alkali, as
to remove every particle of resinous and glutinous matter previous to the chlorine steep.
This, if not attended to, becomes a source of great annoyance to the printer in his sub-
sequent operations, from the difficulty of obtaining sufficiently good whites without injuring
the colors. The high-pressure kiers patented by Barlow, and which are fully described in
the article BLEACHING, have been found to facilitate the thorough scouring of the cloth very
much at a less cost than the old kiers.
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Till about the year 1760, the printing of linens or caliceros was done by hand, wooden blocks being employed, on which the pattern is raised in relief. About this time a modification of the press used for printing engravings was adapted to printing with flat engraved copper plates on fabrics. This press was used to produce certain styles only, generally single colors, where delicacy of outline was required, shaded or stippled work being also introduced. The printing by blocks in several colors was the principal mode still, till, in 1785, the cylinder printing machines were invented by a Scotchman named Bell, and brought into successful use at Mossley, near Preston, by the house of Livesey, Hargreaves, and Co. The house of Oberkampf, of Jouy, in France, almost immediately adopted the invention, and have been frequently considered, in France at least, the originators of the machine; but it is now pretty certain that the honor of the invention is due to Great Britain. The introduction of the cylinder machine gradually caused the demise of the flat press, the London printers continuing to use them long after the Lancashire printers had given them up; the first cylinder machine was used in London in 1812. Blocks are still freely used for some descriptions of prints, such as woolen or mouseline de laine goods, and also for introducing colors, after printing by the cylinder and dyeing, &c.—the cylinder not being capable of fixing in colors, after the piece has once left the machine. A block-machine, called the Perrotine, was introduced in France in 1834 by M. Perrot, and is still extensively used there, but though tried in this country, it never came into general use. It executes as much work as twenty hand printers, and for the special purposes for which it was invented is a satisfactory machine; the patterns capable of being printed by it are, however, limited in size, in consequence of the narrow width of the blocks. Surface printing, or printing from cylinders engraved in relief, was an invention preceding by a few years the engraved copper plates, but apparently not in general use. In 1800, a Frenchman named Ebingar patented somewhat the same sort of thing, and in 1803, James Burton, of the house of Peel, at Church, invented the mule machine, which worked with one or two engraved copper cylinders, and one or two wooden rollers engraved in relief. This machine is very little used now, the impression produced by it not having the precision of that from copper rollers, and improvements in engraving copper rollers having given the printer many of the advantages possessed by the surface roller. Quite lately, however, Mr. James Chadwick has patented a species of surface roller which promises to become useful. The ordinary stereotyped patterns described hereafter are adapted by screws to a brass or other metal roller, which is then fitted on the mandrel used with the ordinary engraved rollers, and a firmness and solidity thus given which was never possessed by the wooden surface roller.

In block printing every color is printed separately, the printer going all through the piece with one block; the rest of the colors are next separately fitted into their places by the appropriate blocks, and the piece is then ready for the subsequent operations for raising the colors. Calico intended for printing by block is always smoothed by the calender, the object being to leave the cloth stiff, so as to facilitate the printer joining the different block impressions. When pieces that have been printed by machine are required to have other colors inserted by block, as, for instance, the groundings in of blues, yellows, greens, &c., after printing and dyeing in madder colors, the same sort of process is adopted, the pieces being dried and calendered, and then printed by blocks technically termed grounds; these grounds are cut from sketches or tracings, taken from the dyed piece when calendered, and, consequently, fit accurately those parts which are intended to be blocked. The groundings-in of colors, after the operations of dyeing, were formerly done by pencils, which were merely small thin pieces of wood, which were dipped in the color, and the necessary portions of the patterns, such as leaves, &c., painted in by hand. Of course, this method soon gave way to blocks; but the use of these pencils was continued down to a comparatively recent period for certain colors, such as pencil-blue, which, being a solution of reduced indigo, was too speedily oxidized when spread on the sieve, and required instant application of the pencil. Even this color was eventually applied by block, by a peculiar kind of sieve.

Of late years the tedious hand labor of cutting or coppering blocks has been much reduced by stereotyping; when the pattern has several repeats on the block, a casting in type-metal being made of the pattern, and as many of these as requisite arranged on a plain block, and securely nailed down. It is obvious that the matrix once made, an infinite number of castings can be easily produced; the skilled labor is therefore reduced to a small portion of what was formerly requisite. The ordinary way of making the mould is to draw or trace on a small block of pear tree, (sawn across the grain, so that the pattern is put on the end of the grain,) the pattern to be typed. Slips of copper of varying thickness, but uniform width, are then driven down to a certain distance in the wood, just as in the ordinary way of coppering blocks. When the pattern is thus completed, the slips are pulled out, of course leaving the pattern indented in the wood; the block is now rubbed with chalk, and a border about 1/16 of an inch deep of card nailed round the block. Melted type-metal is now run in level with the top of the card, and when cold, a tap with a hammer on the under side of the block easily detaches the type, which requires very little trimming to be ready
for putting on the block; when a number of these are arranged on a block, the surface is filed and ground on a stone till perfectly level. The introduction of Burch's patent typing machine, still further simplified the stereotyping process. In this beautiful invention the matrix is formed by steel punches of varying shapes, which are moved up and down by a stirrup and lever, and which are kept heated by a gas flame ingeniously applied, to the temperature sufficient to char wood, and by moving the block about under these punches and depressing them, the pattern is burnt into the wood to a uniform depth, and the labor of cutting and bending slips of copper, &c., done away with.

The Tobying sieve is a mode of applying with one block several colors at once, whereby the cost of several blocks is saved, and, what is of more consequence, the cost of labor is very much reduced, as one printer produces the same result as the combined efforts of several.

Whenever designs are composed of colored parts, where each color lies separate, and where the outlines of the colored parts are not too close together, a sieve of the following construction is made use of, (fig. 96)—A block of wood is scooped out in hollow compartments, e, which vary in size and number, according to the number and extent of the shades to be printed; these compartments communicate by tubes, n, at the bottom, with reservoirs, s, at the sides of the sieve; over the compartments is then stretched tightly a woollen sieve; the surface of this cloth is cemented with melted resin string about ¼ of an inch thick, following the configurations of the compartments; the use of this is to prevent the colors mixing and becoming blended at the edges. Colors are now put in the reservoirs, which are kept filled up above the height of the cloth, so that a gentle pressure is exerted against the under side of the sieve. The colors are made of such a thickness as to pass through the cloth, and keep the upper surface moist, but still not too thin, or they would spread when printed. The sieve being thus prepared, the block is furnished with guides, which, working against the sides of the sieve frame, constrain the block to be always dipped in one place, and thus each part of the pattern finds itself furnished with its proper color.

Sometimes the compartments for the colors are made of metal when required to be durable, so as to serve for a large number of pieces of the same pattern.

Where colors are required to melt into one another, technically called raiDowes; (fondes, Fr.,) the following apparatus is used,—a & (fig. 97) is a rectangular frame c.
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wood, about 6 inches deep, 2 feet long, and about 1 foot broad. On this frame is stretched, by means of small hooks, a woollen cloth, and the frame then laid on the elastic surface of the usual swimming tub, the cloth downwards and pasted or gummed to the oilskin cover of the tub. At one end is now put the color reservoir v, which consists of a wooden or metal box, divided into water-tight compartments longitudinally by strips of thin metal; this box is of such a width as to fit easily into one end of the frame, and resting on a board of the same size, fixed across the frame; the depth of the box may be about 4 inches, and the width about 8 inches; but this is regulated by the number of colors to be blended or rainbowed. A semicircular piece of wood, of nearly the same width as the frame, is covered with printer's blankets, and a handle formed on the top, so that the teerer can move it backwards and forwards. The color lifter, c c, is a flat piece of wood just covering the color box; on the under side of this are inserted wooden pegs, as v, at certain places determined by the width of the stripe of rainbowed color, and the number of shades composing it. These pegs are of turned wood, about ¼ of an inch thick at the small end, and about ½ of an inch at the thick end, this end being also recessed so as to lift more color; they are nearly as long as the color box is deep. In the figure, suppose it is desired to produce on the sieve two stripes, say r of dark green in centre, and two shades of green at each side, and v of chocolate in centre, purple next, and drab next, at each side, the color-box is filled thus:—in No. 1 compartment put the darkest green; in No. 2, the medium green; in No. 3, the palest green; in No. 4, the chocolate; in No. 5, the purple; and in No. 6, the drab. The color lifter is so studded with pegs, that when put in the color-box, the pegs 1, 2, 3, 4, 5, and 6 respectively, dip into their appropriate colors. The brush, or semicircular roller, g, is then moved up to the top, as shown in the dotted lines, the color lifter being then lifted up out of the color-box is held a moment till the color has ceased dropping from the pegs, and then lifted over, and the pegs allowed to deposit the color on the sieve, as shown by the black spots 1, 2, 3, 4, 5, and 6. The lifter is then returned to the box, and a fresh portion of color lifted, and deposited, as before, at a different part of the sieve, the spots of color being of necessity all in straight lines; the brush, g, is then moved backwards and forwards by the teerer till the colors are sufficiently rubbed together or blended at the edges. It is necessary to observe, that the thickness of the colors must be pretty uniform, and sufficiently thin to allow them to mix at the edges. By this means one color is made to melt insensibly into another, and a beautiful shaded effect produced on the sieve, and consequently on the piece, when printed from a block dipped on it.

The annexed cuts are taken from the "Traité de l'Imprimerie des Tissus," of M. Persoz. Fig. 98 is a vertical section, and fig. 99 an elevation.

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A, cast-iron framework. B B B, cast-iron tables, planed smooth, over which circulate the blanket, the backcloth, and the piece that is printed; c c c, sliding pieces, to which the block
holders, 5, are screwed, and causing the engraved blocks, 2, to move alternately against the woollen surface, from which they receive the colors and the stuff to be printed, by the action of the arms, 4 and 5, the supports of which, 6, rest on the frame, A, and which act, through the medium of connecting rods, on the beams, 7, keyed to the slides, c. The lower of these slides, being in a vertical position, takes by its own weight a retrograde movement, regulated by a counterweight. E E E are movable color-sieves, keyed to connecting rods, and receiving from the power applied to the machine the kind of movement which they require. These sieves, which are flat, and covered with cloth on the surface opposite to the blocks, slide in grooves on the sides of the tables, and receive from the furnished rollers the colors which they afterwards transmit to the blocks. F F F are the color troughs filled with color, and furnished each with two rollers, 8 and 10, the last of which, dipping into the troughs, are charged with color, which they communicate to the roller, 8, the latter being covered with woollen cloth; and these, in their turn, transmit their color to the sieves, F, on which it is spread by the fixed brushes, G. As it is important to be able to vary at pleasure the quantity of color supplied to the sieves, and consequently to the blocks, the rollers, 10, are in connection with levers, 11, which, by means of adjusting screws, bring them into more or less intimate contact with the rollers, 8, and consequently vary the charge of color at pleasure.

The blanket, backcloth, and fabric are circulated as follows:—At the four angles formed by the three tables, n, are rollers, 1, armed on their surface with needle points, which prevent the cloths from slipping as they pass round, and thus secure the regular movement of the stuff to be printed, a movement determined by the toothed wheels, 21, (fig. 99,) fixed at the extremities of the axes of these rollers. a is a roller for stretching the endless web, resting with the two ends of its axes on two cushions forming the extremities of the screws, 12, by which the roller can be pushed further out when required, to give the cloth the necessary tension. n is another tension roller, supporting the blanket and backcloth. k is a roller which serves similar purposes for the blanket, the backcloth, and the fabric in course of being printed. t, the blanket, which in its course embraces the semicircumference of the roller, o, passes over the roller, k, and behind k, to circulate round the cylinders, i, and over the surfaces of the tables, n. l is a cylinder from which the backcloth is unwound, being first stretched by the roller, n, and then smoothed by the scrimping bars, 13, from which it proceeds to join the blanket on arriving at the roller, k. m, a roller, from which the fabric to be printed is unrolled by the movement of the machine, first passing over the scrimping bars, 14, and joining at k the blanket and backcloth, which it accompanies in their course till it arrives at the roller, o, when it separates and passes off in the direction of the line, n, to the hanging rollers, where it is dried.

The machine is put in movement, either by a man with a winch-handle, or by power communicated by a strap which passes over the pulley, 18. This pulley has several diameters, so as to give several speeds; it is loose on the driving shaft, and carries catches
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which lock into those of a sliding catch-box on the shaft, when the machine is to be put in movement. The movement of the machine is intermittent because the printing is intermittent; moreover, it must be so regulated that the fabric advances a distance exactly equal to the breadth of the blocks, and that it moves forward whilst the sieves are charged with color from the rollers 8 8. This result is obtained by means of a regulator, or dividing wheel 20. The wheel 21, fixed at the extremities of the axes of the cylinders 1, and having each the same number of teeth, receive their movement from a central wheel toothed in the same manner, and placed behind the wheel 20. This last receives an alternating motion from a rack, 24, fixed in a copper piece, 25, and which rises and falls alternately, being keyed at its lower end to one of the spokes of the wheel 28. By varying the position of the point at which the end of the rack is connected with the spoke 26, the length or range of its movement is proportionally changed, and more or less of the teeth of the wheel 20, are made to pass, which renders proportionally, greater or less, the advance of the cloth at each movement; and this is further regulated by a ratchet wheel placed at d. At each half turn of this last, the lever 22 raises the catch or pallet, and throws out of gear the wheels 21 during the other half turn; but as in the working of these wheels there would be inevitably a backward movement, this is prevented by a key, mounted on the shaft of the axis of the wheel 20, and a brass wire, which, after making a turn and a half, or two turns, on this shaft, is stretched by the weight 23, which offers a sufficient resistance to any recoil. The slides or block-holders are put in motion by the wheels 27 and 28, gearing with the larger wheel 29. And to vary their action at pleasure, both for causing the blocks to bear more or less strongly on the sieves, so as to be more or less charged with color, and likewise for attaining the exact pressure, which suits best for the color to be laid on, it is sufficient to move the points of junction, 16 and 17, to a greater or less distance from the point marked 15, which constitutes the centre of oscillation of the beams that work the slides. The movement of the sieves is controlled by that of the cam 11, 30, which works them all three by putting in motion a shaft with which they are respectively geared. The furnishing rollers receive their movement from gearing with pinions on the axes of the rollers 8 8. The general working of this complex machine remains to be described. When put into regular motion, and the three blocks have delivered their impression exactly at the same instant, three simultaneous movements then commence.

1st. The stuff advances a distance exactly equal to the breadth of the blocks, and with it the blanket and backing cloth, so that the portion of the fabric which leaves the third block behind it, is fully printed; that which was under the second advances opposite the third; that which was under the first, moves along to the second; and a fresh breadth of white or unprinted fabric arrives opposite the first. 2d. While the cloth is advancing as above stated, the sieves take the place which they occupy in the section, fig. 98, that is to say, the first on the right hand rises, the second moves from left to right, the third descends, and in this movement all their press slightly on the furnishing rollers 8, from which they receive the color, which has been spread uniformly by the brushes 9. 3d. In the mean time, the slides, or block-holders, by a forward movement, push the blocks against the sieves, to charge them with color, and the blocks, at the same time, receive from the slides a gentle backward movement, during which the sieves deviate from their position; the blocks then return upon them, and are drawn back again after being applied to a new part of the color surface. When these simultaneous movements have taken place, the action of the machine proceeding without intermission, the sieves move back from before the blocks, and these are pushed up against the latter, printing the position of the fabric that is stretched upon them. This brings the machine to that position at which the description commenced; and this succession of movements is renewed and repeated as long as the operation lasts; the printer having it always in his power to suspend the advance of the stuff whilst the working of the blocks and sieves continues, so that the color may be reapplied to the same part of the fabric as often as may be required for a good impression.

There have been several attempts at block-printing by machinery in this country, amongst which the machines of Mr. Joseph Burch have been most successful; but from one cause or another, none of them have ever come into general use, and it is unnecessary, therefore, to particularize them.

Before proceeding to describe the more complex machines which print upon cloth several colors at one operation, by the rotation of so many cylinders or rollers, it is advisable to give some insight into the modern method of engraving the copper cylinders. These were formerly engraved altogether by hand, in the same manner, and with similar tools, as the ordinary copper-plate engravings; till the happy invention of Mr. Joseph Perkins, of America, for transferring engravings from one surface to another by means of steel roller dies, was with great judgment applied by Mr. Locke to calico-printing, so long ago as the year 1808, before the first inventor came to Europe with the plan. The pattern is first reduced or increased in size to such a scale, that it will repeat evenly over the roller to be engraved; and as rollers are of varying diameters, owing to old patterns being turned off, &c, this
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drawing to scale has to be adopted for every roller, the exact circumference of the roller being taken and the pattern arranged in accordance with this. This pattern is next engraved in intaglio on a roller of softened steel, which is of such a size that one repeat of the pattern exactly covers its surface; generally these rollers are about 3 inches long, and from \( \frac{1}{2} \) an inch to 2 or 3 inches in diameter. The engraver aids his eye with a lens when employed at this delicate work. This roller is hardened by heating it to a cherry-red in an iron case containing pounded bone-ash, and then plunging it into cold water; its surface being protected from oxidizement by a chalky paste. This hardened roller is put into a press of a peculiar construction, called the clamping machine, where, by a rotatory pressure, it transfers its designs to a similar roller in the soft state; and as the former was in intaglio, the latter must be in relief. This second roller being hardened, and placed in the engraving machine, is employed to engrave by indentation upon the full-sized copper cylinder the whole of its intended pattern. The first roller engraved by hand is called the die; the second, obtained from it by a process like that of a milling tool, is called the mill. By this indentation and multiplication system, an engraved cylinder may be had for £1, which engraved by hand would cost £5. The restoration of a worn-out cylinder becomes extremely easy in this way; the mill being preserved, need merely be properly rolled over the copper surface again. The die roller is made of such a size that its circumference is exactly a fractional part of that of the mills, say one-half, one-third, one-fourth; then in the clamping machine the die revolving in contact with the mill repeats its surface so many times on the surface of the mill. By this means as little skilled labor as possible is used. When a pattern having more than one color is to be engraved, the drawing is reduced to scale as before, each roller being made of the same diameter; then a tracing is made of each color, which is engraved on a separate die and mill—a mill being required for each color—which engraves its separate copper color; when these rollers come to be worked in the printing machine, each roller fits its part of the pattern into place, and the original pattern is reproduced. The annexed drawings of engraving machinery are from those made by Messrs. Gadd and Hill, of Manchester, to whose courtesy we are due also the drawings of the printing machines and their drying apparatus hereafter described. Fig. 100 is a front view of the clamping machine, and fig. 101 is a side view of the same. 

![Diagram](image)

A cast-iron framework; \( a \) a headstock screwed on the framework \( a \); \( c \) a sliding piece, capable of movement from back to front on the headstock \( b \); the position being determined, it is secured by the screw shown under \( c \); the roller \( v \) revolves in bearing attached to the sliding piece \( c \); the supporting piece \( x \) has a motion backwards and forwards on the supporting piece \( o \), which moves up or down; \( e \) is a small steel roller, which again supports the die roller seen in the centre of the drawing. The roller \( v \) is of softened steel, called the mill, which revolves in bearings attached to the headstock, which has a sliding movement on the slide block \( u \), which is moved from right to left by the screw, \( t \), worked by the lever \( k \). \( i \) is a pinion gearing into the toothed wheel \( \gamma \), and turned by the winch handle \( \varepsilon \); the shaft \( r \) has a sliding movement through the wheel \( \gamma \), and carries the boss \( o \), which has a square aperture to
receive the centre of the mill, which is squared to fit into it. \( q \) is a screw used to tighten and keep in the desired position the saddle pieces \( e, c \), which together are pushed up or down to meet the varying size of the die.

The die \( d \) having been hardened, is inserted in the machine resting on the auxiliary hard steel roller \( e \), which again rests on the supporting piece \( e \); the die being in contact with the hard steel roller \( n \), the soft steel roller or mill \( e \) is next forcibly screwed up in contact with the die, rotary motion being given to the roller \( n \) by the toothed wheels; those portions which are in intaglio in the die become in relief on the mill. It is then ready for the machine engraver to transfer its pattern to the copper roller. \( \text{Fig. 102} \) is an elevation of

the engraving machine. \( A \) is a mandrel which carries the copper roller \( h \); the mandrel is fitted in the universal joint \( c \), which is secured on the shaft of the wheels \( d, n \), which are a double pair of wheels for the purpose of altering the speed from fast to slow, and are moved by the winch handle or pulley. The lever \( x \) is fitted, works loosely on the shaft, on which is keyed the wheel \( r \). By means of the screw \( o \), the lever \( n \) can be secured to the wheel \( r \). By this contrivance the motion termed rocking is effected, that kind of motion being required when the pattern repeats at great intervals. The mill works in bearings attached to the pillar and carriage \( h, n \), which is moved from right to left by the screw \( t \); the mill is forcibly pressed against the copper roller by a weighted lever, which forces down the bearings of the mill in the pillar \( h \); this lever cannot be shown in the figure, but is at right angles to the roller. The mill being in contact with the copper roller, revolves with it simultaneously on the roller being moved by the wheels \( n, o \) or the lever \( n \); and consequently impresses or engravures its pattern on the copper roller; when the mill has traversed the circumference, it is then moved to its next relative position by the screw \( t \), which moves the pillar and carriage \( n \); the exact distance the mill moves is determined by an index on the wheel \( k \), which is divided into segments, corresponding with the number of repeats laterally on the roller. The apparatus shown at \( k \) is used occasionally when the machine is employed for turning off an engraved pattern, which, however, is generally performed in a slide table, and is unnecessary further to describe here.

Etching by nitric acid is largely employed in engraving for calico printing, the following being the process:—The copper roller is first coated all over with a thin coating of bituminous varnish, and when dry put in a machine which rules lines about the \( \frac{1}{2} \) of an inch apart all over the surface, the lines all running in one direction and diagonally to the axis, the varnish being cut through by the ruling point. The pattern is then traced on in the usual manner. All the parts that are intended to be blank, are then painted in with the bituminous varnish by hand; generally the outlines are put in by skilled operatives, the filling-in being done by girls or boys; when dry, the roller is immersed horizontally in a bath of diluted nitric acid, and kept there for a few minutes, during which time the acid attacks and deepens the lines which are unprotected by varnish; the roller is then removed, well washed with water, and the varnish removed by oil of turpentine; the pattern is found etched with diagonal bars, which in a good engraving should be nearly level with the blank parts of the roller, the interspaces being sufficient to supply the color. The outlines of the pattern are generally completed with the graver. This mode is well adapted for giving a deep engraving, which is necessary for printing coarse fabrics. When a pattern is worn down it is easy to renew it, by simply painting up the blank parts and etching deeper by nitric acid.

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In 1854, William Rigby patented a mode of transferring patterns to copper rollers by a modification of the penograph. The pattern to be engraved is drawn on an enlarged scale, and put on a bed curved to an arc of a circle, a tracer being then moved over all the lines of the pattern by a beautiful, but simple, arrangement of machinery, a tracer executed, on a varnished roller, a reduced copy of the pattern on the circular bed. In a patent, dated 1st January, 1857, Rigby introduced an improvement whereby any number of tracers could be simultaneously worked on the roller, by the simple movement of the tracer on the pattern; thus all the repeats of the pattern could be executed at once. The method is becoming very extensively adopted, and, independent of several large printers having begun engraving on this system, a very large establishment, "The Burlington Engraving Company," has been commenced with a view to engrave on this principle. All descriptions of engraving cannot, however, be done on this plan. The process is the following:—

The pattern is first enlarged to five times its size: this is conveniently done by the camera. The paper pattern being set in the camera, an enlarged copy is thrown on a table in a darkened room, and is then easily traced on paper. It is then transferred to a thin zinc plate, and this plate is then engraved with a coarse graver, the lines of the engraving being adapted for the tracing point to work easily in. The zinc pattern, if of a two- or more colored pattern, is colored for the guidance of the operator. It is then laid on the curved bed of the penograph machine, and a varnished roller being mounted on the machine, a number of tools, corresponding in number to the repeats laterally, and carrying diamond points, are placed in contact with the roller. The operator then carries the tracer successively into all the lines of the pattern, a lever allowing the points to touch the roller only when necessary. The pattern is thus traced by the etching points on the roller one-fifth of the size of that on the zinc plate, or the same size as the paper drawing. The roller is then printed and etched with nitric acid, as before described. A reference to the annexed engravings will more clearly illustrate this system.

In figs. 103 and 104, a represents the cylinder to be operated upon; and b, the bed or table for the reception of the enlarged pattern or original device; c, the tracer, which is made to traverse in the direction of the arc of the bed or table, and by means of its connection with the carriage d, the rail d, and the connecting arms e e, communicates part of a revolution to the bar or axis f, and thence to the cylinder through the dies g g, on which the cyinder rests. The cylinder being thus moved in a rotary direction, will receive from the tools in contact with it diminished copies of the transverse lines which may have been gone over by the tracer on the enlarged pattern or device. The tracer e being connected with the carriage, h, which travels along the rail d, will, in passing over a line running longitudinally with the machine, communicate a partial revolution to the wheel l by means of the bands of steel j j, similar to watch springs, which pass under and over the small wheels k k, and are passed round and secured to the large wheel l, which is mounted on the vertical shaft m, carrying at its upper end the small drum m', round which passes the steel band n, secured at each end to the pieces o o. These pieces are secured by bolts or screws to the sliding frames p, to which the upper tool bar or bars q, which support the graving, drilling, or etching tools r r, are fixed. Thus any motion of the large wheel l will be imparted to the drum m', and by it through the steel band n to the sliding frames p, and the tool bars q, and, consequently, to the tools r, thereby transferring to the cylinder diminished copies of any lines in a lateral direction that may be gone over by the tracer. It will be evident that the result of the simultaneous action or compounding of the two motions, by passing the tracer over any diagonal or curved line, will be the production of a diminished copy of such diagonal or curved line by each of the tools. a is a trundle with a vertical link and appropriate leverage, by which the tools may be brought in contact with the cylinder when required; t t are counterbalance weights for the connecting arms e e, lower rail d, &c.; u and e represent a worm and wheel for the purpose of giving the roller an extra partial revolution when it is required to engrave upon a different portion of the circumference of the cylinder; and to effect a similar purpose in the longitudinal direction, the tool bar may be made to shift in its sliding frame with an adjusting screw attached to it, by means of which any degree of exactitude in the setting of the tools may be obtained.

In the machine, as shown in the accompanying drawings, the design executed on the cylinder would bear the same proportion in size to the enlarged pattern on the bed or table that the small drum m bears to the large wheel l, and the radius of the disks g g, to the radius of the circular bed; but by the adaptation of wheels and disks of different diameters, any desired proportion between the pattern engraved and the enlarged pattern may be adopted.

In fig. 105, representing a mode of giving an alternate reverse action to the tools and bars p p', are the bars, to one of which a longitudinal and motion given at the same time to the other bar by means of the links or rods b b', connected to the beam or lever c, working on the pin or fulcrum d' attached to the framing c'. This arrangement of the machine is suitable for turnover patterns.
In figs. 106 and 107 the tool holders are adapted for employing two or more rows of tools, the members of the two rows being placed in alternate holders, or otherwise, according to the pattern. It is evident that by slight modifications in the form of the tool holders the tools may be made to occupy any position on the surface of the cylinder, thus affording great facility for placing the tools and making them applicable for step patterns or other suitable sketches.

Figs. 106 and 107 show two such modifications, in which \( f' \) is the copper roller; \( g' \) the line of fulcrums or centres upon which the tool holders \( k' \) and \( k' \) vibrate, the said tool holders with their tools being lifted off by the cam \( f' \), and advanced to their work by the weights \( w' \), which can be adjusted with any required nicety.

In figs. 108 and 109 is shown another arrangement of tools with swivel bars, the swivel bars being shown at \( p' \), and placed and held in the desired position by the screws \( q' \). To the bar is attached the carriage \( r' \), to one end of which is connected the tool holder \( s' \), in which is a projection \( t' \), acted upon by a beam or lever \( u' \) working on a fulcrum in the carriage \( r' \). The tool is lifted off the roller \( r' \) by means of the cam \( w' \), and returned to its work by means of a spring or Indian-rubber band \( x' \), attached to the slide \( r' \). It will be perceived that, independently of the slot or slide in the tool holder, great change of position is obtained by simply shifting the carriages longitudinally.

The "eccentric engraving," or etching, of Mr. Lockett, of Manchester, produces on a varnished roller the most curious variety of configurations, by means of diamond points, moved by very elaborate machinery, the patterns being the result of eccentric movements given to the tracer by a combination of machinery. In this case the exact effect that will be produced by any given modification of the machine cannot be determined, though an approximation can be made; but when a pattern is produced, and notes taken of the relative positions of the wheels, &c., the same pattern can at any time be reproduced. This system is applicable principally to groundworks, or, as they are termed, "covers." It is impossible in the scope of this article, to give a clear idea of this machine, as a very elaborate set of drawings would be required.

With regard to the 2 and 3-colored machines, we must observe, that as the calico in passing between the cylinders is stretched laterally from the central line of the web, the figures engraved upon the cylinders must be proportionally shortened, in their lateral dimensions, especially for the first and second cylinder.
Cylinder printing, although a Scotch invention, has received its wonderful development in England, and does the greatest honor to this country. The economy of labor introduced by these machines is truly marvellous; one of them, under the guidance of a man, to regulate the rollers, and the service of two boys, to supply the color troughs, &c, being capable of printing as many pieces as nearly 200 men and boys could do with blocks.

In mounting two or more cylinders in one frame, several adjustments become necessary. The first and most important is that which insures the correspondence between the parts of the figures in the successive printing rollers, for unless those of the second and subsequent engraved cylinders be accurately inserted into their respective places, a confused pattern would be produced upon the cloth as it advances round the pressure cylinder.

Each cylinder must have a forward adjustment in the direction of rotation round its axis, so as to bring the patterns into correspondence with each other in the length of the piece; and also a lateral or traverse adjustment in the line of its axis, to effect the correspondence of the figures across the piece; and thus, by both together, each cylinder may be made to work symmetrically with its fellows.

Fig. 110 is an end elevation of a 4-color printing machine, and Fig. 111 is a section of same: the same letters of reference refer to both. A is the cast-iron framework, bolted to a corresponding framework by the bolts B, with a space of from 3 to 4 feet between; C is the pressure cylinder, about 2 feet diameter, of iron, but hollow, and between 3 and 4 feet long, according to the sort of cloth the machine is intended to print; D are the copper rollers, the width of a piece of cloth; E are wrought-iron mandrels, on which the copper roller is forced by a screw press, the mandrel being about 4 inches diameter where the roller fits on, but with journals of smaller diameter. The roller is made with a projecting piece inside, about \( \frac{1}{2} \) an inch broad, and \( \frac{1}{4} \) of an inch deep, extending all the width of the roller; this tab, as it is called, fits in a slot cut in the mandrel, which causes it to turn without slipping on the mandrel; the pressure cylinder or bowl C, rests with its gudgeons in bearings or bushes, which can be shifted up and down in slots of the side cheeks A; these bushes are suspended from powerful screws F, which turn in brass nuts made fast to the frame A. These screws counteract the pressure upwards of the two lowest rollers, and enable the bowl to be lifted out of the way of the rollers, &c, when they have to be removed. G and H are sliding pieces, moving in arms of the framework, by means of screws H H. These sliding pieces carry the bearings of the mandrels; to them are also attached the color boxes and doctors. The screws H work in female screws F, which form part of a system of jointed levers K. These levers are for the purpose of giving an additional pressure or nip to the rollers B, the pressure being also elastic. There are four pairs of levers, each pair bearing upon one mandrel. It will be sufficient to describe one side only, both sides being precisely alike. The two highest rollers are pressed against the cylinder by the compound levers K', which have attachments to the arms of the framework at F, and to the inside of the main framework at G and X' as fulcrums, and are jointed together at H, but the bent levers H, G, I, merely fit into sockets I, of the horizontal levers X' K', which are weighted at the ends, K', by movable weights made to fit expanded parts. The two lowest rollers are pressed
against the cylinder by the system of compound levers \( k'' \), which have attachments to the framework at \( k \) and \( x' \) as fulcrums; the screws \( n' \), \( n'' \) working in female screws \( r' \), \( r'' \), as in the other set of levers. For convenience of removing the rollers, color boxes, &c., these levers are provided with a hinged piece \( x \), in a socket \( o \), on the top of which work the screws \( l', l'' \), which, by means of the female screw in the lever \( k', k'' \), serve still further to regulate the pressure; the lever \( k', k'' \) is shown as when the machine is printing; but when the rollers, &c., are to be removed, the lever is lifted by the handle, and the hinged piece \( x \) pulled over, the lever with its burden being then lowered down: the weighting of these levers, which are partly outside the machine, is best seen in figs. 110 and 111, where \( l \) are the weights, \( q \) are color boxes, the sides and bottom of which are made of sheet copper, and the ends of gun-metal; in each end is a slot, which receives the brass journals of the wooden furnishing rollers \( p \), which are wrapped with a few folds of coarse calico, and, by revolving in the color and against the engraved rollers \( n \), supply it equally all over with the color; the superfine color is next wiped off by the color doctors \( r \). These doctors are thin plates of steel or brass, which are mounted in doctor shears, or plates of metal screwed together with bolts; the shears have journals which rest in bearings movable backwards and forwards by the screws \( s \); the doctors are kept in close contact with the engraved roller by levers and weights, for the way of arranging which, see fig. 112, where \( a, n, c \), are the levers attached to the doctor shears. On the ends of these levers weights are hung, and by this means the doctors are pressed forcibly against the roller.

After printing the pattern on the piece, the roller \( p \) is cleaned from threads or dust by the lint doctors \( v \), pressed against the roller by the screws \( s \), fig. 111; any loose threads from the piece are prevented by the lint doctors from going into the color, and consequently under the cleaning doctors, where, by preventing them from perfectly wiping the blank parts of the roller, smears on the piece would ensue. The color boxes are mounted on wooden boards, to give them greater strength, and are tightened up against the roller, by the screws \( k, r \) and \( w, w \); the lower pair of color boxes are removed from the copper roller when not in use by the handles \( v \), after detaching the screws \( w, w \). There is a toothed wheel slipped on to each mandrel, working into a toothed wheel on the axis of the furnishing roller, which ensures the copper roller and furnishing roller always turning together. By means of an eccentric, fixed on the axis of the pressure bowl, and connected with each cleaning doctor, a regular vibratory movement is given to them, which prevents the doctor being worn down unequally. Sometimes for the highest rollers, and especially in machines of more than four colors, the cumbersome color box is dispensed with, and a doctor inserted in a curved frame is applied to the roller instead. In this arrangement the doctor forms the bottom of the color reservoir, and is pressed strongly against the roller; the curved frame stopped off at the sides with a piece of copper curved to fit both roller and frame, and which
is padded with a piece of folded cotton cloth, forms the color box. This doctor box takes but little room, and wastes but little color, but is only used for the uppermost rollers. Neither of these arrangements can be shown in Fig. 111. The roll of pieces is shown at $a$, wound on the wooden roller $b$, the axis of which rests in bearings at the end of the arms. The piece is conducted under a small wooden roller, next over a square iron bar, and next against the scrimping bar $v$, thence over the wooden roller $x$, round which also pass the gray piece $d$, and the woollen blanket $e$. The scrimping bar is a bar of iron or brass, with curved surface, furrowed by grooves, cut right and left from the centre. See Calico Printing, vol. 1. In passing over this bar, the cloth is stretched equally from the centre, and any
folds or creases removed. In order that the piece may be constantly stretched, the roller \( b \) is provided with a wooden pulley, round which passes a leather strap, one end of which is made fast to the framework, and to the other is attached a weight; the friction of the strap against the pulley causes a retarding action of the piece, and consequently keeps it stretched.

Fig. 113 is an elevation of a 12-color machine, which is inserted to show the way in which all machines are driven. The large spur wheel is keyed on the axis of the pressure bowl, and works into pinions staked on the mandrels; there is a peculiarity about these pinions, or box wheels, as they are called, which may be observed in Fig. 113, but is shown on an enlarged scale in Fig. 114, which is a box wheel detached. This wheel may be compared to the fine adjustment of a microscope, as by means of it the rollers receive the final and delicate adjustment so as to register accurately with one another. It consists essentially of two parts: the disk \( A \), carrying the cogs; and the hollow axis \( n \), carrying a disk at one side, and the connecting piece and screw \( c \) at the other. The part \( A, A \), or shell of the wheel, is about 10 inches diameter and 8 inches broad across the cogs; one side of the shell is cut out to receive the plate shown by dotted lines. This plate is provided with the hollow axis \( n \), which comes through the shell, and projects about 8 inches, the part projecting being cut through at \( F \); fastened to it also is the connecting piece \( c \), in which works the screw \( n \); this screw just fits in two projecting lugs \( a, a \), cast on the shell \( A \). The screw nut \( n \) forms part of the axle piece, and works in the slide \( n \). When this wheel is used, it is slipped on the mandrel which carries the copper roller, and a cotter is driven through the cleft axle and through a corresponding cotter hole in the mandrel, thus firmly connecting the mandrel and wheel; the mandrel and roller being put in their place in the machine, the cogs of the mandrel wheel work into the main driving wheel, as shown in Fig. 113. The coarse adjustment of the rollers being made when putting them in their places, the fine adjustment is made by turning the screw \( n \). It is obvious that the screw \( n \), by pressing against the lugs \( a \) of the shell \( A \), which is geared into the driving wheel, will turn the mandrel and roller without moving the cogs. By this arrangement, any roller may be moved round about 2 inches at any time after being fixed in its place. All machines of more than one color are fitted with these wheels, which, indeed, are indispensable.

In Fig. 118 is also shown a piece of apparatus attached to the framework for the purpose of cleaning the cloth from dust and threads before printing. This apparatus, patented by John Coates, of Manchester, is shown on an enlarged scale in Fig. 115. It consists essentially of a brush and a roller, covered with card or the wire material used in cotton-carding engines; these, with the gearing, are attached by the straps of iron \( n \) to the ends of the rods \( A, A \), care being taken that the roller \( a \) is placed parallel to the printing machine, and the apparatus sufficiently high to be over the head of the person engaged at work behind the machine, and convenient for him to reach out the roller and brush, when they require
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cleaning. The piece passes over the small roller c, whether delivered from the "roll," or "beam," as at x or o; it then goes under the wooden rail p, and over a brush r, and afterwards, at r, it comes on to the card roller, which is turned by the plain roller a (over which the piece passes) the contrary way to the piece, so that the card catches any loose material, and prevents it again adhering to the piece.

Four, five, and six-color machines, similar to the above, are now at work in many establishments in Lancashire, which will turn off a piece of 28 yards per minute, each of the three or four cylinders applying its peculiar part of the pattern to the cloth as it passes along by ceaseless rotation of the unworned wheels. At this rate, the astonishing length of one mile of many-colored web is printed with elegant flowers and other figures in an hour. When we call to mind how much knowledge and skill are involved in this process, we may fairly consider it as the greatest achievement of chemical and mechanical science.

The general course of printing is thus performed:—The pieces to be printed are wound on a beam, and, last of all, a few yards of common coarse cotton or calico, kept for this purpose; this is for the printer to fit the pattern on, to save good cloth. The roll of cloth being put in its place behind the machine, the printer's assistant stations himself behind to guide the cloth evenly, and pluck off any loose threads he may see. The machine printer stands in front, and, after having fitted the pattern on the cloth, attends to supplying the color-boxes with color, and regulating any misfitting or inequality in the printing. The machine then prints rapidly. After running through 30 or 40 pieces, the printer stops the machine, removes the doctors, and files them anew to a bevelled sharp edge.

To prevent the blanket being too soon soiled, it is usual to run gray or unbleached pieces between the blanket and the white pieces. The blanket, gray, and printed pieces are dried separately. There are several ways of drying after the machine. The fig. 116

may be taken as representing a good and effective method. Behind the printing machines there is a hot room, in which is placed the whole of the drying apparatus. This room is kept closed, and is ventilated as to let out the steam, &c.; it is of necessity of much higher temperature than the printing apartment. Above the printing machine is fixed a framework, which carries the supports for the rolls of gray pieces, and a long range of steam chests, a a. These steam chests are the same width as the machine, about 1 foot broad and 3 or 4 inches deep, and are connected one with another by bent pipes at the end. The range of steam chests is continued through an aperture in the wall into the hot room, and below them is an arrangement of steam cylinders, turning on hollow axes, through which steam is admitted. The course of the blanket, gray, and piece, will be seen on reference to fig. 116, in which the shortest arrow shows the course of the blanket, the longest arrow the course of the printed pieces, and the middle-sized one that of the gray pieces. The white pieces leave the roll b, passing over a wooden roller, and thence round the cylinder along with the gray and the blanket. After receiving the impression, the piece passes over a small roller at the edge of the framework, and thence along the top of the steam chests, on the roller being so regulated as to keep the pieces close to the chests, but not touching them. It passes along the straight length and down the incline; on leaving the chests, it passes round the cylinders Nos. 6, 5, and 4, being so stretched by rollers as to embrace nearly the whole of the cylinders; it then passes under the framework and up through another narrow aperture in the wall, being conducted through a planing-down apparatus, which has drawing rollers at the end of a pair of arms, which move in a segment of a circle, and so fold the piece backwards and forwards in a loose pile. The gray and the blanket, on leaving the cylinder, proceed together over a roller at the under side of the steam chests, along which they travel as far as the roller c, where they part company, the blankets passing down over the cylinders 1 and 2, thence under these cylinders and over and under the rollers d d, returning along under the steam chests round rollers e e, and so again into the machine. The gray pieces, after leaving the roller c, pass along under the side of the chests
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to the roller $f$, thence round the cylinder 3, the rollers $g$, $g$, being finally wound on a beam at $h$. When the roll of grey pieces $i$ is exhausted, the roll $h$ is put in its place, the grey pieces being run through the machine two or three times, according as they are more or less stained, and then sent to the bleaching house.

Scarcely any print works are without several 5 and 6-color printing machines, and the printers of goods intended for hangings, which are generally of elaborate floral designs, employ machines capable of printing from 10 to 20 colors at once. These machines are necessarily of very large dimensions. Fig. 117 is an end view of a 20-color machine, made by Messrs. Gadd and Hill, of Manchester, for Mr. Kay, of Castleton Print Works, and is employed in printing very beautiful floral patterns on woollen fabrics, in imitation of those produced by hand labor in France.

The system of turning cylinder machines, patented by Mr. Joseph Leese, possesses several advantages. In this plan a small high-pressure oscillating engine is attached directly to the axis of the large cylinder, thereby dispensing with the heavy gearing and shafting required when machines are turned by a large stationary engine; the machine printer also has perfect command over the speed of the machine, and can fit the pattern, when it is turning very slowly, with more convenience than on the usual system. On this system also machines can be put down in any portion of the works, and are independent of the stationary engine.

In surface printing, the cylinder or roller is in relief, just as the wooden blocks used by hand, and the manner of working them is shown in Fig. 118, which is the section of an 8-color surface machine of Gadd's. $AA$ is the framework; $B$ is the bowl or cylinder, which is hollow, and made with arms inside; $C$, $C$ are the surface rollers, supplied with color by the endless web or sieve $FF$, revolving round the wooden tension rollers $D$, $E$; the roller $E$ is screwed down so as to press the sieve on the furnishing roller $R$, which revolves in the copper color box $G$; the two tension rollers next to the surface roller move in slides, so that, by means of the screw $H$, the sieve can be pressed against the surface roller; on leaving the furnishing roller $R$, the sieve is wiped by the doctor $r$, screwed lightly against the sieve by the screw $K$.

The printing roller being in relief, there is no necessity for the complicated arrangement of levers as in the ordinary machine, and consequently the surface machine is much more simple. It is only adapted for patterns of little delicacy, as the outlines are apt to be not well defined; the colors, however, from being laid on the top of the cloth, are very rich, hence for woollen fabrics the surface machine is well adapted.
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Pieces for printing by machine are stitched together end to end, which is usually done by girls, but the use of stitching machines is rapidly becoming general, and probably will soon become universal. One of these machines, found advantageous, is shown in fig. 119.

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This machine was the invention of Charles Morey, in 1849. A pair of wheels are fitted with leaves on their peripheries, and gear into one another like cog-wheels. These wheels are mounted in suitable bearings fixed to a sole plate, and receive rotary motion by means of a winch-handle. The centre of the teeth of both wheels is cut away, so as to form a circular groove between the two teeth which happen to be together. Opposite to this groove, and attached to the frame, there is a bracket which carries a sliding piece, with a spiral spring wrapped around it. In the end of the sliding piece, which passes through the bracket, there is a receptacle for the eye end of a needle, the point of which rests in the groove formed by the wheel; the needle is threaded, and the fabric to be stitched placed behind the wheels, to which rotary motion is communicated, whereby the fabric is successively folded into undulations, which, as the operation proceeds, are forced on the point of the needle; when the needle is full, and the piece at the other side of the wheels, the needle is...
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pushed back on the spring, removed from the machine, and the thread drawn through the pieces, which are then basted or stitched together. This is a very rapid mode of stitching ends of pieces together; but where a number of pieces are stitched end to end for the purpose of being put through several operations without unstitching, a finer description of stitching is required, and a machine, known as the American machine, and patented by Newton in 1853, is frequently used. This machine consists of an arrangement, whereby a bearded needle is employed for throwing a line of bearded stitches into the fabric. The pieces are hung double on pins projecting from two circular racks, which move in grooves formed in the face of a circular frame. These racks are driven by pinions taking into their teeth, and thus the piece ends are passed under the action of the needle, which, having a quick reciprocating motion similar to that of the needles of stockings frames, and being in like manner supplied with thread, is passed backwards and forwards through the fabric, and thereby leaves a chain of loops on the inner face thereof. Carried by the same arm is a stiletto, which' pieces holes in the fabric to allow of the needle passing freely through the same. The machine being rather elaborate, will be described in the article Sewing Machines.

Pieces are also frequently gummed together at the ends, which is done by pasting the ends for about 1¼ inches with paste or gum, and, after laying one on the other, drying them immediately on a steam pipe in front of the operator. This mode is advantageous for some purposes, as when the pieces come, in the subsequent operations, into hot water, they are easily detached one from the other.

By whichever of these modes the pieces are joined together, they are then wound in rolls of about 40 pieces by a machine called a candojy, which winds them on the wooden beam which fits in at the back of the printing machine; the cloth during the operation of winding becomes stretched laterally quite smooth, by the aid of one or two grooved stretching bars, a due degree of strain being kept on the piece by it passing under and over several plain wooden bars, and to the axis of the wooden beam which receives the pieces being suspended weights which keep it forcibly in contact with the wooden drum which turns it by friction. In this machine, the ends of the axis of the beam pass through slots, which allow it to rise as the pieces become wound on, and the diameter consequently increases. If fewer pieces than 40 are to be printed in one pattern or coloring, it is usual to stitch a few yards of old cloth between two pieces where the change is intended to be made; by this means the printer, on coming to the waste piece, stops his machine, and fits another pattern or changes the colors without damaging good cloth.

The doctors used in cleaning off the superfluous color from the rollers, are generally the blades of steel, of a thickness varying from 52 to ¼ of an inch, according to the sort of engraving on the roller; but some colors, such as those containing salts of copper, would be too corrosive on a steel doctor, and in this case doctors of a composition like brass are used. They are filed to a bevelled edge, and require to be retouched with the file after printing from 10 to 30 pieces. The cylinder or drum, in contact with which revolve the copper rollers, is wrapped round with a cloth called "lapping," which is generally a coarse strong wooden cloth of peculiar make, and is folded tight on the cylinder about ¼ an inch thick. The blanket is next put on and drawn tight: this blanket is a very important part of the machine; it is a thick woolen web, about 40 yards long, and requires to be made with great care, so as to be uniform in texture, thickness, and elasticity. If the blanket is uneven, it has the effect of throwing the blanket into confusion at the uneven places.

A good blanket will serve to print 10,000 pieces, being washed whenever loaded with color, and then is suitable for covering the tables of the block printer.

In the year 1835 Messrs. Macintosh and Co. patented an Indian-rubber blanket, which consists of several thick cotton webs, cemented together with dissolved Indian-rubber. This blanket is very useful and economical for some purposes; the surface being very smooth, great delicacy of impression is obtained, and, when soiled, it is not necessary to remove it from the machine, as it is easily washed with a brush whilst revolving on the machine. An Indian-rubber blanket will print 20,000 pieces, which is twice as much as a woolen one will do, the price per yard being also lower. Several descriptions of these blankets are made by Messrs. Macintosh, some of them having a coating of vulcanized Indian-rubber on the face that is printed from, thereby giving a still more elastic surface. A great improvement has been recently made in these Indian-rubber blankets by shrinking or preparing the cotton previous to cementing, according to the patent process of Mr. John Mercer, viz., by soaking in strong alkali, and afterwards in dilute sulphuric acid; this process contracts the fibre to a certain extent, and the cloth is found to possess a great increase of strength. When made into blankets, they are found to be more capable of resisting the severe strains of the printing process, and consequently many more pieces can be printed from them than the old sort. They are made by Mr. Richard Kay, of Accrington, and are coming into general use. The woolen blanket, however, seems to be preferred for several styles. Several patents have been taken out for printing without blankets, but have never come into
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general use; but recently a mode of printing with gray or unbleached calico has come into use, which is very favorably spoken of. In this method a roll of gray cloth is so disposed behind the machine that the fabric can be conducted five times through the machine before finally going away to be wound on a beam for removal. There are, therefore, 5 layers of cloth under the white calico when printing, which give a sufficiently elastic bed for printing from; and very delicate shapes can be got. Any given part of the gray cloth is then transferred on the pressure cylinder, and consequently 1 piece of gray cloth is used to print 5 pieces of white. Gutta percha pressure cylinders, or "bowls," have been suggested by Dalton, an English printer; but, though theoretically preferable to iron, they do not appear to be much used.

The proper hygrometric state of calico when printing should be attended to; very dry calico does not take colors or mordant nearly so well as when containing a certain amount of hygrometric moisture. Practically this is attained by the bleached pieces being stored in the "white room," generally several hundred pieces in advance, and they easily absorb sufficient moisture from the air to be in a proper state for printing on.

Pieces after printing by either block or machine are rarely put through the next operations at once, but are for the most part hung in spacious airy chambers in folds, from an arrangement of rails at the top of the room. These chambers are kept at an equable summer temperature, and in proper hygroscopic conditions, due ventilation being also provided. These "ageing rooms," as they are called, are in several print works of enormous dimensions, and are generally separate buildings. Those of Messrs. Edmund Potter & Co., and Messrs. Thomas Hoyle & Co., in Lancashire, may be particularized as forming quite a feature in the works. The pieces stay in these chambers from 1 to 6 days, according to the style of work, during which time the color which was deposited on the outside of the fibre gradually permeates it, and becomes more firmly attached; a portion of the base being deposited, and acetic acid given off in vapors. Where colors are required to absorb a certain amount of oxygen, such as iron mordant, catechu browns, &c., they find the necessary conditions here. On the proper ageing of printed goods depends in a great measure the success of many styles; should the room be too hot or too dry, imperfect fixation of the color ensues, and meagre and uneven tints are obtained in the subsequent operations. In countries where in summer the atmosphere is dry, great difficulty is found in ageing properly. In America catechu browns have been known to require weeks before being of the proper shade. These are of course exceptional cases; the scientific printer knows how to combat these evils by the introduction of water vapor, or even by heating his ageing room over a reservoir of water, with certain open binding for floor; many colors also may have deliquescent salts introduced.

In England the process of ageing is of pretty uniform duration.

Quite recently several printers have begun to adopt a method of "ageing," which promises to revolutionize the old way of hanging for several days, and thus occupying a large space. In a patent of Mr. John Thom for sulphuring mousseline-de-laines, a cloth is made for using the same apparatus, or a modification of it, for passing calico printed goods through a mixture of air and aqueous vapor. Pieces, after leaving the hot room in which they are dried after printing, are run over rollers arranged in a narrow room, above and below. A very small quantity of steam is allowed to escape into this room, which is kept slightly warm by the steam-pipes. The pieces, on issuing from the apparatus, should feel soft but not moist; they are loosely folded together, and stay in this state one night and are taken to the dyehouse next day. It is even stated that this one night's age may be dispensed with, and the pieces dunged off after five or six hours' age.

The thickening of mordants and colors is a subject of very great importance to the printer. It is obvious that a mere solution of salts or coloring matters, such as used in dyeing, cannot be used in printing a pattern; capillary attraction speedily causes such a solution to spread beyond the limits of the pattern, and nothing but confusion is the result. A proper degree of insipissation is then essential. To the capability of very thick color being printed by engraved plates or rollers under severe pressure is due the superior smartness of outline characteristic of goods produced by these means. Where color can be laid on the outside of the cloth, so as to penetrate as little as possible to the other side, much brighter shades are produced. In order to obtain the most brilliant shades of color, it is necessary that the cloth act as a sort of mirror behind the color, which cannot be the case if the fibre is perfectly saturated with color. Independent of this, a great economy of coloring material follows from the proper application of the color or mordant to the face only. This is especially noticeable in madder goods, where the mordant, if printed in excess, is apt to give up a portion from the cloth in the dyebeck, thereby consuming a certain quantity of madder in pure loss.

The color-house should be a spacious apartment on the ground floor, with the roof ventilated in such a manner that the steam produced finds a speedy exit; at one end, or down one side, is fixed a range of color-rooms, varying in size, and supplied with steam and cold water. Color-rooms are usually made to swing on pivots, whereby they are easily emptied and cleaned. A range of this sort, as manufactured by Messrs. Storey & Co., of
Manchester, is represented in fig. 120. This range consists of 8 double-cased copper pans, containing from 1 to 28 gallons, riveted together at the top, wired at the edges, and made perfectly steam-tight; they are supported on cast-iron pillars, and are so arranged or fitted as to swivel or turn over when the color is required to be emptied, by means of a brass stuffling box attached to pan, and working in the corresponding part attached to pillar on the one side, and moving at the other on a plain brass nozzle, supported by a pedestal projecting from pillar, the nozzle having a blank end, thereby cutting off the communication of steam, which is carried to the following pan. They are also supplied with a condense tap to carry off the waste steam and water. Each pillar in the range, except the last, is supplied with a brass tap on the top, with 3 flanges, to connect the steam and cold water pipes, as more fully explained hereafter.

A, fig. 120, is a copper pipe, with one blank end, and open at the other with flange for the admission of steam, which passes through the downward-bent pipe marked b, in connection with the brass tap on top of pillar, the plug of this tap being open at bottom to admit the steam down the pillar as far as the stuffling box, marked c, through which it rushes into the casing of pans, and out by the condense pipe d, when required. c is a copper pipe, with one blank end and open at the other, for the admission of cold water for cooling the color after boiling, and is likewise connected with the tap on top of pillar, as shown in fig. 121, marked f, the water passing through precisely in the same manner as the steam in A. d is the condense pipe, with one blank end and open at the other, with flange, underneath the pans, to carry off the water or steam, and is supplied with ground brass nozzles, to fit the condense tap at bottom of pan, being accurately adjusted, so that in the swivelling of pan it leaves its seat and returns perfectly steam-tight. Fig. 121 represents an end view of range, showing more fully the position and connection of steam and cold water pipes to brass tap, the cold water pipe running along back of range, the steam pipe above, parallel with centre of pans, and the downward-bent pipe in front; and likewise the stoppage in pillar, so far as is necessary there should be an aperture for the steam or water to meet the brass stuffling box. In this fig. is also shown the copper pipe, with elbow swivel tap, for supplying pans with cold water, (one pipe to supply two pans,) and fixed on top of cold water pipe exactly opposite pillar, as further shown in fig. 122 marked g. Fig. 123 is an end view of range, with pillar cut, in order to show the position of condense tap at bottom of pan, and its connection with condense pipe, and where the point of separation takes place in swivelling, by the line marked h. It will be seen by the foregoing that the
process of boiling and cooling is rapid and certain, every thing being accurately adjusted and steam-tight throughout the whole apparatus.

The colors are placed in these pans and stirred well all the time they are being boiled; good stirring is very essential to produce smooth colors. This was formerly done by hand with a flat stick, but lately the best print works have been fitted with machinery over the pans to stir mechanically. A very effective plan of this sort is represented in figs. 124 and 125. It is that of Messrs. Mather and Platt, of Manchester, the boilers in this drawing being not reversible, though the plan can be just as easily adapted to that descrip-

![Diagram](image_url)

Fig. 124 is a front elevation; fig. 125 is a transverse section, and fig. 126 is a sectional plan, the same letters referring to all. a is a horizontal shaft above the pans, fitted with a pair of mitre wheels, b b, for each pan. The vertical wheel b is not keyed on the shaft e, but is brought into connection with it when required by the catch box c, which slides on a key on the shaft, and revolves with it (see small cuts); the catch box is worked by a lever handle d, and thus motion is given to the vertical shaft e. The shafts e and f are both supported by the framework f, fastened to the wall; the shaft e is terminated by the frame g h g, the centre of which, h, is a continuation of the shaft e; and the wings g are hollow to carry the shafts k, which are surrounded by the cog wheels i k, which gear into a cog wheel l on the shaft e. The agitators n n are made of flat brass rod, and are curved to fit the bottom; they are connected with the shafts k k by a hook joint, which is steadied by the conical sliding ring m; the agitators thus hang from the shaft e, and nearly touch the bottom of the boiler. When the shaft e is put in motion, the agitators have two movements, one round each other, and also each on its own axis; as they are set at right angles to each other, as shown in fig. 126, it follows that no part of the pan can escape being stirred. When the color is made, the piece m is slid up on h, and the agitators unhooked and taken out, the waste of color being very trifling, in consequence of the agitators being outlines only. The saving of labor effected in a color house by this machinery is very great, as, after turning on the steam, the pan may be left to itself till the color is finished.

From the great variety of substances used in mordants and colors, of very different chemical properties, a variety of thickening substances is required. Chemical combination between the mordants or color and the thickening substance is to be avoided as much as possible, for such combination may be regarded as so much pure loss, the fibre of the fabric not being able to decompose and assimilate them. Several circumstances may
require the consistence of the thickening to be varied; such as the nature of the mordant, its density, and its acidity. A strong acid mordant cannot be easily thickened with starch; but it may be by roasted starch, vulgarly called British gum, and by gum arabic or senegal. Some mordants which seem sufficiently inspissated with starch, liquefy in the course of a few days; and being apt to run in the printing-on make blotted work. In France, this evil is readily obviated, by adding one ounce of spirits of wine to half a gallon of color.

The very same mordant, when inspissated to different degrees, produces different tints in the dye-copper; thus, the same mordant, thickened with starch, furnishes a darker shade than when thickened with gum. Yet there are circumstances in which the latter is preferred, because it communicates more transparency to the dyes, and because, in spite of the washing, more or less of the starch always sticks to the mordant. Gum has the inconvenience, however, of drying too speedily, and forming a hard crust on the cloth, which does not easily allow the necessary capillary attraction to take place, and the tints obtained are thin and meagre. The substances generally employed in thickening are:

1. Wheat flour.
2. " starch.
3. Torrefied wheat starch, or British gum.
4. Torrefied potato farina.
5. Gum substitutes or soluble gums.
7. Gum tragacanth.
8. Salep.
9. Pipe-clay or china-clay mixed with gum Senegal.
10. Sulphate of lead.
11. Molasses.
12. Dextrine.
14. Lactarime.
15. Gluten.
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Those most used are the first seven. The rest are only adapted for special styles or colors. The artificial gums produced by roasting starch or farina are very largely in use. The action of heat on starch causes a modification in it. According to the degree of heat and its duration a greater or less modification ensues, the higher the heat, the more soluble in water the gum, but also the browner and of least thickening properties. The addition of various acids and alkalies to starch or farina before calculation, causes them to become soluble at lower temperatures than without; different acids also produce different results; those most generally used are nitric, acetic, muriatic, oxalic, and recently hetic acid has been proposed by Pocchlin. The proportion of acid used is very small, and, though the effect is produced, the acid disappears during calculation. Small quantities of alkalies are also used for special modifications of these gum substitutes. The making of these gums is a distinct branch of trade, and finds employment for large capital and numerous hands. In giving the receipts for the various colors, care will be taken to specify the nature and proportion of thickening to be employed for each color; a most important matter, often neglected by English writers upon calico printing.

It is often observed that goods printed upon the same day, and with the same mordant, exhibit inequalities in their tints. Sometimes the color is strong and decided in one part of the piece, while it is dull and meagre in another. The latter has been printed in too dry an atmosphere. In such circumstances a neutral mordant answers best, especially if the goods be dried in a hot flue, through which humid vapors are in constant circulation.

In padding, where the whole surface of the calico is imbued with mordant, the drying apartment or flue, in which a great many pieces are exposed at once, should be so constructed as to afford a ready outlet to the aqueous and acid exhalations. The cloth ought to be introduced into it in a distended state; because the acetic acid may accumulate in the foldings, and dissolve out the earthy or metallic base of the mordant, causing white and gray spots in such parts of the printed goods. Fans may be employed with great advantage, combined with hot flues. See Ventilation.

The mordant and thickening, or the dye decoction and thickening, being put in one of the copper pans, is stirred by hand or machinery and boiled till perfectly smooth; the steam then being shut off, cold water is admitted to the double casing, and the color cooked. It is then emptied out of the pan into a straining cloth, stretched over a tub, and strained to remove all gritty particles, which would be very injurious to the copper rollers. A very useful straining machine has been recently invented by Dollfus Mieg & Co., and patented in this country. This machine is shown in fig. 127. It consists of a case or cylinder, in which a piston is worked, either by hand or power, to press the color through a cloth made of cotton, linen, hair, or other suitable material at the bottom of the case or cylinder; or, instead of the said cloth, a wire gauze may be used. The bottom of the piston may be made of wood, copper, brass, gutta percha, caoutchouc, or other suitable material. The manner of working the apparatus will be clearly understood by reference to the drawings, in which fig. 127 is a side elevation of the said machine or apparatus, and fig. 128 a front elevation of the same. A represents the case or cylinder, which is strengthened at its upper part by the iron band n, and also at its lower part by the ring a. The skeleton plate b, which forms the bottom of the cylinder, is removable, and sustained by the four hooks c. To disengage the plate b, springs are fitted on the ring d, which act upon two of the hooks c, so as to throw them out from under the grid b. Upon the ring a the second ring d is laid, which supports the circular handle e. The upper parts of the four hooks e lay upon four inclined planes fitted on the ring d. The machine operanda is as follows:—If the ring d is turned right or left, the skeleton plate b, on which one of the said cloths or wire gauze has previously been placed, will be brought firmly up to the extremity of the cylinder a; and if the said cylinder be filled with coloring matter, the piston m, being worked by the pulley e, the wheels r, o, n, l, s, k, and the rack l, will force it through the cloth or sieve, to be received in a vessel under it for the purpose; and by a proper arrangement of the teeth of the said rack t, the piston can only descend to any required point in the cylinder. To facilitate the working of the apparatus and increase its general efficiency, the cylinder is fixed on pivots at n, so that it may be easily inclined or brought towards the operator for the purpose of introducing the coloring matter or cleaning the vessel. To the ring or band n are fixed the two handles f and the two catches h. The catches being raised from the notch n on the frame r, the cylinder may be pulled forward by means of the handles f till the hooks, being acted upon by a spring, re-engage themselves at k on the lower part of the frame r, and vice versa. On the shaft s is placed a second wheel q, by which a reverse motion is obtained, and the piston m raised to its original position.

Colors for printing by block are for the most part thinned in the same manner as those for machine, but are made thinner, since very thick color cannot be applied by block. Some substances also can be used in block printing that are inapplicable to machine, such as pipe-clay and china-clay, which, however finely ground, still contain
gritty particles, which would speedily scratch and destroy the delicate engraving of the machine rollers.

A spacious drug room is attached to the color-house where all the drugs used are kept away from the steam of the color-house. Near the color-house should be a well-appointed laboratory, where drugs can be tested and experiments made.

Formerly, all the decoctions and mordants used in print-works were made on the spot, but the trade having very much extended, the manufacture of the various mordants and decoctions of dyewood is now a separate business, and printers can be supplied with these articles at the same or in some cases a lower rate than they could be produced for on the works, the quality also being uniform and good. The printer now only makes for himself a few unimportant articles. The province of the foreman color maker, who is generally a well-paid and responsible servant, is to combine these primary materials so as to form the different colors required for the different styles of work; as the taste of customers varies, he is required to be able to make any given variation of shade at will, and be able to judge of the quality of the various materials submitted to him. The ordinary decoctions that are kept in stock in the color department are:

- Logwood liquor.
- Peachwood liquor.
- Sapan liquor.
- Quercitron bark liquor.
- Gall liquor.
- Persian berry liquor.
- Cochineal liquor.
- Fustic liquor.
- Catechu liquor.
- Ammoniacal cochineal liquor.
- Extract of indigo.
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And the various mordants and solutions are:

Red liquor, or acetate of alumina.
Iron liquor, or acetate of iron.
Buff liquor, or pyroligneous liquor of iron.
Pernigrinate of iron.
Protomurate of iron.

Protochloride of tin in solution.
Oxyurate of tin in solution.
Nitrinate of copper in solution.
Acetate of copper in solution.
Lime juice.

Ammonia liquor.
Acetic acid.
Pyroligneous acid.
Nitric acid.
Muratic acid.
Sulphuric acid.
Caustic soda liquor.
Caustic potash liquor.

Many other dry acids and salts are also kept in stock. For the constitution of the various mordants and their preparation see MORDANTS.

It would be impossible to particularize all the styles of calico printing. The variety is infinite; but they may be broadly classed as follows:

I. Madder styles, varieties of which are:

a. The simplest form is a pattern printed in mordants on white ground, such as black and red; black, red, and purple; black and two reds, &c., chocolate being sometimes substituted for black, and brown from catechu being also introduced; these are dyed with madder, the ground remaining white.

b. Any or all of the above mordants, together with lime juice, technically termed acid, printed, and a fine pattern printed all over or covered in purple or light chocolate, then dyed madder. In this style the red is a peculiar one, termed resist red; and the result when dyed is, that the acid and red have prevented the purple or chocolate fixing on those parts, the red remaining pure and the acid having formed a white, the rest of the ground being covered with the fine pattern or cover; of this style large quantities are printed in black, purple, and acid, and covered in pale purple, the cover roller being any small full pattern, and this not being required to fit to the other pattern, a great variety of effects may be produced by varying the cover: often a still weaker purple is padded or blotched in a plain shade all over the piece, and in this case the only white in the pattern is that reserved by the acid.

c. The French pink style, which is wholly various shades of reds or pinks, and is printed in one or more shades of red and acid, then covered or blotched in pale red, then dyed madder and subjected to a peculiar clearing with soap, whereby pink shades of very great delicacy are obtained.

All these are what are termed fast colors, and having, after dyeing, undergone severe soaping, cannot be altered by the usual domestic washing process.

II. The same styles are dyed with garancein instead of madder; heavier and darker colors being employed. These goods are not soaped, garancein producing bright colors at once, but the shades, though still classed as fast colors, do not possess the permanence of those dyed with madder.

III. The first style is frequently relieved by lively colors, such as green, blue, yellow, &c., blocked in after dyeing and clearing; these colors are generally what are termed steam-colors, being fixed by steaming the cloth, and afterwards washing in water only, or the printed or dyed pattern is covered with a resist paste blocked on, and various shades of drab, slate, buff, &c., printed with a small pattern all over; sometimes these colors are mordants, to be subsequently dyed with cochineal, quercitrin bark, &c., or they may be colors composed of dyewood decoctions, mixed with mordants, and are fixed by passing through soda or other solutions. The result in either case being that the original pattern, generally a group of flowers, being protected by the paste which prevented the subsequent color fixing thereon, stand out pure, the rest of the ground being covered by the small pattern or cover. White may be also reserved by the paste, and frequently these white parts are blocked with blue, yellow, green, &c., as before.

IV. Padded styles.—In these the cloth is first padded (as will be hereafter explained) all over with a liquid mordant, dried and printed in spots or figures with strong acid, or discharge as it is called, then put through the dyeing operations necessary for the shade required; the printed spots remaining white, and the rest of the piece one plain shade. The white portions are frequently relieved by steam-colors blocked in.

V. Indigo-blue; a style of considerable importance. In this, a resist paste, either alone or accompanied by resist yellow, or orange mordant, is printed on white calico, which is then dipped in the indigo vat, till the shade of blue wanted is obtained. If yellow or orange is present, these colors are raised with dichromate of potash liquor. The peculiar colors printed in this style have the property of preventing the indigo fixing on the printed parts, and the result is dark blue ground, with white, orange, or yellow spots, steam-colors being sometimes blocked in the whites.

VI. China-blue, a modification of the indigo-blue style, but in this case the pattern is produced by indigo-colors, printed on white cloth: the pieces are next put through a pecu-
lier process fixing the indigo in the cloth, the result being blue figures on white ground. All indigo styles are fast or permanent.

VII. Turkey-red and discharge.—On dyed Turkey-red cloth is printed an acid, or acid solutions mixed with pigments or salt of lead; the printed pieces are passed through chloride of lime solution, when chlorine is eliminated by the acid colors, and discharges the red. The pigments or lead-salt being fixed in the cloth at the same time, after washing and chroming where yellow has to be obtained, the piece presents a pattern, bitten as it were in the Turkey-red ground. Black is also printed along with the other colors. A modification of this style is the well-known Bandanna style used for handkerchiefs. Turkey-red cloth is folded in a hydraulic press on a lead plate perforated with a pattern. When a sufficient number of folds are made on this plate, a precisely similar plate is put on the top, so as to register accurately with the bottom one; pressure being now applied, the cloth is squeezed tightly between the two plates, a top being opened above the upper plate, solution of chlorine is forced through the perforations, and in its passage through the cloth, discharges the dye; the chlorine liquor is followed by water, and the operation is finished: the pieces when removed from the press being discharged, according to the pattern of the lead plates.

VIII. Steam-colors.—In this style colors are formed from mixtures of dyewood extracts and mordants, together with various acids and salts, and being printed on calico which has been mordanted with peroxide of tin, the pieces are exposed to steam at 212° in close vessels, which causes an intimate union of the calico with the dyewood extract and iron from that subsequent washing with water removes only the thickening substance, and leaves the cloth dyed according to the pattern in various colors. Woollen fabrics and de-laines are always printed in this manner, and also often silk; animal fabrics not being well adapted for mordanting and dyeing in the same manner as cotton fabrics, owing to the peculiar property of wool to absorb coloring matters, which renders the obtaining of whites an impossibility where the wool is steeped in a dye decoction. These steam-colors are very brilliant and tolerably permanent to light, but do not withstand hot-soap solution which alters their shades.

IX. Spirit-colors are made in somewhat the same manner as the steam-colors, but contain larger quantities of mordant and acid, and will not bear steaming, because the calico would be too much tendered by the acid, and are therefore only dried and hung up a day or two, and then washed in water. They are the most brilliant colors, but generally fugitive and are not much used.

X. Bronzes, formerly a style in large demand, but now almost obsolete; done by padding the cloth in solution of protochrome of manganese, precipitating the oxide by means of alkali, peroxidizing this by chloride of lime, and then printing on colors composed of protochrome of tin, and pigments or decoctions; the protochrome of tin immediately de-oxidizes, bleaching the brown oxide of manganese, and, where mixed with decoctions or pigment, leaving a dyed pattern cutting through the ground.

XI. Pigment-printing.—The colors in this class are the same pigments as used by painters, such as Scheele's green, ultramarine blue, chrome yellow, &c, and, being quite insoluble in water, are, so to speak, cemented to the fibre. The vehicle used for fixing these is generally alumina, which coagulates when the cloth is steamed, and impregnates both cloth and fibre with the coagulum; of course these colors, though not altered in shade by soap, are detached in part by severe treatment, such as rubbing, &c.

First Style: Madder.

Madder styles being the most important, demand the most detailed descriptions. The colors used are of the class termed mordants, which, not coloring matters themselves, act by combining with both cloth and coloring matter. They are generally the acetates or pyrolignites of iron and alumina.

Red Liquor is the technical name of the pyrolignite of alumina used as mordant for red, &c.

Iron Liquor is the pyrolignite of iron used as mordant for black, purple, &c.

The preparation of these liquors on a large scale forms a separate business, and will be found described under the head MORDANTS.

Fixing Liquor.—For a long time it has been customary to add to black and purple colors, or mordants, some substance which has a tendency to prevent the oxide of iron from passing to the state of peroxide. The oxide of iron necessary to produce the best results with madder is a mixture of protoxide and peroxide of iron, probably the black or magnetic oxide, though this point is not precisely determined. If the oxide should pass to the red oxide state, inferior shades are produced; and the object of the printer introducing fixing liquor into his color is to prevent this injurious tendency.

The earliest fixing liquor used was a solution of arsenious acid; and though other fixers have from time to time been introduced, the preparations of arsenic still hold their ground. A very good fixing liquor, that has been much used in France and England, is made as follows:—
No. 1. Purple fixing Liquor.—\(\frac{3}{2}\) gallons water, 1% gallon acetic acid, 9 lbs. sal ammoniac, 9 lbs. arsenious acid; boil till the arsenic is dissolved, and let stand till quite clear.

In 1844, Mr. John Mercer patented an assistant mordant liquor for the same purpose, which was made as follows:

No. 2. To 100 lbs. potato starch, add 374 gallons water, 123 gallons nitric acid, specific gravity 1.3, and 4 oz. oxide of manganese. The chemical action which takes place amongst these ingredients is allowed to proceed till the nitric acid is destroyed. To the residuum thus produced are added 50 gallons of pyroligneous acid, and the compound is the assistant mordant liquor in a flat state to add to the various mordants used in printing and dyeing. The intention in making this liquor is to carry on the decomposition of the nitric acid and starch as far as possible without forming oxalic acid, and as little as possible of carbonic acid, which is gently aided by the catalytic action of the oxide of manganese, preventing the formation of oxalic acid. Apparently there is formed by this process saccharic acid, or an acid in a low state of oxidation, which is the active agent in preventing the peroxidization of the iron when added to purple mordants. This liquor has been largely used, and is still preferred by some printers. Of late, various fixing liquors have been made and sold by manufacturing chemists, pyroligneous acid and arsenious acid, or arsenite of soda, forming the staple of them; some of these have chlorate of potash added, the object being the formation of arseniate of iron when the cloth is dried, whereby the acetic acid is more speedily driven off; and since arseniate of iron does not pass beyond a certain degree of oxidization in the air, the mordant is kept in a proper state for dyeing good colors. The following is also a good purple fixing liquor:—

No. 3. Purple fixing Liquor.—Boil together till dissolved 2 gallons water, 25 lbs. soda crystals, 221 lbs. arsenious acid. When dissolved, add to 50 gallons wood acid, previously heated to 120° F.; let stand for a day or two till the tar of the acid is settled, and add 3 quarts muriatic acid.

The following madder colors are from some in practical use, and though almost every color-maker has different receipts for his colors, they may be taken to represent the general principles on which these colors are composed.

In all these colors the thickening substance is first beaten up with a little of the liquid till quite fine and free from lumps, then the remainder of the liquid added, and the whole boiled and stirred in one of the double-cased steam-pans till quite smooth; cooled, and strained.

No. 4. Black for Machine. (Madder.)—4 gallons iron liquor at 24° T., 4 gallons pyroligneous acid, 4 gallons water, 24 lbs. flour; boil, and add 1 pint oil.
No. 5. Black for Garancin. (Machine.)—\(\frac{3}{2}\) gallons water, 3 gallons iron liquor at 24° T., \(\frac{1}{2}\) gallon purple fixing liquor, (No. 3,) 24 lbs. flour, 1 pint oil.
No. 6. Dark-red for Madder. (Machine.)—12 gallons red liquor at 18° T., 24 lbs. flour.
No. 7. Pale-red for Madder. (Machine.) —Made by reducing the standard liquor, No. 8, with gum water to the shade wanted: for instance, No. 3 pale-red is 1 of No. 8 and 3 of gum water, No. 9.
No. 8. Standard red Liquor.—10 gallons hot water, 40 lbs. alum, 25 lbs. white acetate of lead; rake up till dissolved, let settle, and decant the clear.
No. 9. 3 lbs. Gum-substitute Water.—10 gallons water, 90 lbs. gum substitute, No. 5 in the list of thickeners.
No. 10. Dark resist-red Madder. (Machine.) see Mordants.—12 gallons resist-red liquor, 18° T., 24 lbs. flour; boil, and when nearly cold add 12 lbs. of muriate of tin crystals.
No. 11. Dark resist-red Machine.—Same as No. 10, but 6 lbs. of tin crystals only.
Of these two last, No. 10 is used when it has to resist a chocolate cover, and No. 11 when it has to resist a purple cover.
No. 12. Pale resist-reds Madder. (Machine.)—Made by reducing resist-red liquor with water, and thickening it. For instance, No. 5, pale-red: 12 gallons resist-red liquor at 5° T., 9 lbs. flour; boil, and add, when cool, 2 lbs. tin crystals.
No. 13. Chocolates are made from iron liquor and red liquor mixed, and the red liquor is a multiple of the iron; as, for instance, 3 chocolate (madder) (machine):—3 gallons iron liquor at 24° T., 9 gallons red liquor at 18° T., 24 lbs. flour, 1 pint oil. No. 6 Chocolate:—1 gallon iron liquor at 24° T., 6 gallons red liquor at 18° T., 14 lbs. flour, \(\frac{1}{2}\) pint oil.
No. 14. Strong red for Garancin. (Machine.)—10 gallons red liquor at 18° T., 2 gallons water, 24 lbs. flour.
No. 15. Resist-red for Garancin. (Machine.)—12 gallons resist-red liquor at 14° T., 24 lbs. flour; boil, and add 6 lbs. tin crystals. This for resisting chocolate.
No. 16. Resist-red for Garancin. (Machine.)—12 gallons resist-red liquor at 14° T., 24 lbs. flour; boil, cool, and add \(\frac{3}{4}\) lbs. tin crystals. This for resisting purple.
No. 17. Brown Standard for Madder.—50 gallons water, 200 lbs. catechu; boil 6 hours, then add \(\frac{3}{4}\) gallons acetic acid, and add water to make up to 50 gallons; take out, and let stand 36 hours, and decant the clear; heat it to 150° F., and add 90 lbs. sal ammoniac, dissolve, and leave to settle 48 hours; decant the clear, and thicken it with 4 lbs. of gum Senegal per gallon.
No. 18. **Brown Color for Madder, (Machine.)—**4 gallons No. 17, 1 gallon acetate of copper, (No. 19,) 2 quarts acetic acid, 2 quarts gum Senegal, water 4 lbs. per gallon.

No. 19. **Acetate of Copper.—**1 gallon hot water, 4 lbs. sulphate of copper, 4 lbs. white acetate of lead; dissolve, let settle, decant the clear, and set at 16° T.

No. 20. **Brown for Madder, (Machine.)—**7 gallons of No. 17, 1/4 gallon of No. 19, 1/4 gallons gum-red, (No. 21.)

No. 21. **Ox red.—**3 gallons red liquor at 18° T, 12 lbs. gum substitute; boil.

No. 22. **Brown for Garancin, (Machine.)—**2 gallons No. 18, 1 gallon 4 lbs.-gum-substitute water.

No. 23. **Brown for Garancin, (Machine.)—**2 gallons No. 17, 2 3/4 gallons 4 lbs.-gum-substitute water, 3 quarts acetic acid, 3 quarts No. 19.

No. 24. **Drab for Madder, (Machine.)—**4 gallons No. 17, 1 gallon protomuriate of iron at 9° T, 3 gallons No. 19, 1 gallon 4 lbs.-gum-substitute water. For garancin, add 4 gallon gum water instead of 1 gallon.

No. 25. **Drab for Madder, (Machine.)—**5 gallons No. 24, 1 quart muriate of iron at 9° T, 5 gallons 4 lbs.-gum-substitute water, 3 quarts No. 19.

No. 26. **Madder Fawns are made by adding to madder drab 1/3, or so, of red liquor, according to the shade wanted.**

No. 27. **Madder Purples.—**Iron liquor, mixed with purple fixing liquor, is diluted with gum water according to the shade wanted. For instance, **No. 4 purple for madder (machine)—**1 gallon of iron liquor at 24° T, 2 gallons No. 3, 4 gallons farina gum water No. 28. **No. 12 purple—**1 gallon iron liquor at 24° T, 2 gallons No. 5, 12 gallons No. 28.

No. 28. **Dark Farina Gum Water.—**10 gallons water, 60 lbs. dark caliehed farina; boil.

No. 29. **Garancin Purples are reduced from iron liquor to the shade wanted with the following gum—**20 lbs. light British gum, 8 gallons water, 1 gallon purple fixing liquor No. 27; boil well, then take out, and let stand 5 or 4 days before using. **Color:** 1 measure iron liquor, 8, 10, 20, 50, &c., of the above gum, according to shade wanted.

No. 30. **Pedding Purples.—**Reduce to shade with the following gum—6 lbs. water, 1 gallon No. 3, 1 quart logwood liquor at 8° T, 9 lbs. flour; boil, and add 5 quarts farina gum No. 28. For instance, **70-peddling purple for machine—**1 gallon iron liquor at 24° T, 70 gallons of the above gum.

Block colors are made from any of the preceding receipts, by making them a little thinner.

No. 31. **Alkaline red Mordant.—**In a vessel capable of holding 12 gallons, put 10 lbs. alum, and dissolve with 5 gallons boiling water, then add gradually 3 quarts caustic soda at 70° T, mixed with 1 gallon cold water, fill up with cold water; let settle, decant and repeat the washing till the clear liquor is tasteless; filter to a pulp, take off, and add to it 5 pints caustic acid at 70° T, boil down to 3 gallons, add 9 lbs. dark gum substitute, and boil again a short time.

No. 32. **Pale-red Alkaline Mordant—**1 measure of the above color and 2 or 3 measures of dark gum-substitute water.

No. 33. **10 Acid.—**1 gallon lime juice at 10° T, 1 lb. starch; boil.

No. 34. **20 Acid.—**1 gallon lime juice at 20° T, 1 lb. starch; boil.

No. 35. **30 Acid.—**1 gallon lime juice at 30° T, 1 lb. starch; boil.

No. 36. **Acid Discharge.—**1 gallon lime juice at 22° T, 1 lb. bisulphate of potash; filter, and thicken the clear with 1 lb. starch.

No. 37. **Acid Discharge.—**1 gallon lime juice at 23° T, 2 lbs. bisulphate of potash; filter, and thicken the clear with 5 lbs. dark British gum.

In the last two colors, the bisulphate throws down a quantity of flocculent matter, which has to be filtered out.

No. 38. **Reserve Paste—**3 3/4 gallons lime juice at 50° T, 2 3/4 gallons caustic soda at 70° T, heat to boil, then, in a separate vessel, beat up 56 lbs. pipe-clay with 2 3/4 gallons boiling water, and add 3 3/4 gallons 6 lbs.-gum Senegal water; add to the other solution, and boil 20 minutes.

No. 39. **Reserve Paste—**4 gallons lime juice at 60° T, 3 gallons caustic soda at 70° T, boil, and add 48 lbs. pipe-clay beat up with 2 quarts boiling water, and 4 gallons 6 lbs.-gum Senegal water; boil 20 minutes.

The above two pastes are used for blocking on madder-work, to protect the pattern from the following covering shades, which are raised with quecitrion bark, &c., &c. No. 38 is a paste used where there are only black and reds to preserve, and No. 39 is used where there is also purple.

**Covering Shades.**

No. 40. **5 Drab.—**1 quart iron liquor at 24° T, 5 quarts water, 2 1/2 lbs. light British gum.

No. 41. **10 Drab—**1 quart iron liquor at 24° T, 10 quarts water, 4 1/2 lbs. light British gum.
No. 42. 5 Drab.—1 quart iron liquor at 24° T., 1 quart red liquor at 20° T., 5 quarts water, 2½ lbs. light British gum.

No. 43. 10 Drab.—1 quart iron liquor at 24° T., 1 quart red liquor at 20° T., 10 quarts water, 5 lbs. light British gum.

No. 44. Olive.—2 gallons red liquor at 12° T., 1 gallon iron liquor at 14° T., 6 lbs. light British gum.

No. 45. Olive.—3 gallons red liquor at 18° T., 2 gallons iron liquor at 8° T., 10 lbs. light British gum.

No. 46. Sage.—9 quarts red liquor at 9° T., 1 quart iron liquor at 12° T., 4 lbs. light British gum.

No. 47. Sage.—14 quarts red liquor at 3° T., 1 pint iron liquor at 12° T., 5½ lbs. light British gum.

No. 48. Chocolate Brown.—6 gallons red liquor at 15° T., 1 gallon iron liquor at 24° T., 104 lbs. light British gum, 2½ lbs. flour.

No. 49. Slate.—3 quarts logwood liquor at 8° T., 2 quarts iron liquor at 24° T., 1 quart red liquor at 18° T., 1 quart No. 50, 7 gallons water, 18 lbs. light British gum; boil.

No. 50. Gold Liquor.—28 lbs. ground galls, 2 gallons acetic acid, 12 gallons water; stir occasionally for two days, and filter.

No. 51. Hazel.—1 quart brown No. 18, 2 quarts bark liquor at 10° T., 1 pint logwood liquor at 12° T., 1 quart cochineal liquor at 8° T., 16-oz. measure No. 52, 4½ quarts 6 lbs. gum-Senegal water.

No. 52.—1 quart nitrate of iron at 80° T., 1 pint nitrate of copper at 100° T.

No. 53. Standard for Bags.—10 gallons water, 40 lbs. copperas, 20 lbs. brown acetate of lead; stir till dissolved, settle, and use the clear; reduced to shade wanted with gum-Senegal water.

No. 54. Chrome-oxide Standard.—3 gallons water, 12 lbs. bichromate potash; dissolve with heat, put in a mug of 12 gallons' capacity, add 3½ pints oil of vitriol diluted with 6 quarts cold water, add gradually 3 lbs. sugar; when the effervescence has ceased, boil down to 3 gallons.

No. 55. Drab.—5 quarts gum-tragacanth water, (8 oz. per gallon,) 2½ quarts No. 55, ¾ pint cochineal liquor at 4° T., ½ pint bark liquor at 8° T.

No. 56. Faen.—1 gallon No. 55, 2 gallons 8 oz.-gum-tragacanth water, ½ gallon brown No. 17.

No. 57. Slate.—1 gallon No. 55, 1 gallon 8 oz.-gum-tragacanth water.

No. 58. Gum-tragacanth Water.—10 gallons water, 5 lbs. gum tragacanth in powder; stir occasionally for 3 days.

No. 59. Fast Blue Standard.—150 gallons water, 18 lbs. indigo in pulp, 24 lbs. copperas, 28 lbs. lime previously slaked; stir occasionally for 2 days, let settle, and draw off the clear liquor, and to every 10 gallons add 1 pint muriate-of-tin liquor at 120° T.; filter on flannel to a thick paste.

No. 60. Fast Blue for Machine.—1 quart No. 60, 6 oz. muriate-of-tin crystals, 3 quarts of water.

No. 61. Fast Blue Standard.—1 lbs. indigo ground to pulp, 3 quarts caustic soda at 70° T., 3 quarts water, and granulated tin in excess; boil in an iron pot till perfectly yellow, when put on a piece of glass.

No. 62. Fast Blue, (Block).—1 quart No. 62, 12 oz. muriate-of-tin crystals, 12 oz. lime juice at 60° T., 3 quarts 6 lbs.-gum-Senegal water.

No. 63. Fast Green.—1½ quarts No. 60, 2 quarts lead gum No. 64, ½ lb. muriate-of-tin crystals.

No. 64. Lead Gum.—1 gallon hot water, 8 lbs. white acetate lead, 4 lbs. nitrate lead; dissolve, and add 1 gallon 6 lbs.-gum-Senegal water.

The course of operation for the styles 1, 2, and 3 above, is to print in one or more of the madder colors; after drying, the goods are hung in the ageing room for a day or two, then brought to the dye-house. The first operation is that termed dunning, which is the same in principle for all varieties of madder or garache goods, and as it is an operation the careful performance of which is of vital importance to the success of the subsequent operations, a somewhat detailed description of it will not be out of place. The process of dunning has for its object:

1. Precipitating on the fibre, by double decomposition, that portion of the mordant which has escaped decomposition in the ageing room.

2. Rendering insoluble and inert those portions of the mordant which are not in direct contact with the fibre, and which, if allowed to diffuse in water only, would fix on and stain the white or unprinted parts of the cloth.


4. Neutralizing the acids which may have been added to the mordants, and which otherwise would dissolve in the water and weaken the colors.

5. The formation, in the case of iron mordants, of a compound of oxide of iron, and
certain organic or inorganic acids which will not become peroxided beyond a certain point. The use of cow's dung, derived from India, has been continued down to the present time, though for several years printers have largely introduced various substitutes.

No very exact analysis has been made of cow dung. Mordin's, which is the most recent and elaborate, is as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>70.00</td>
</tr>
<tr>
<td>Vegetable fibre</td>
<td>24.08</td>
</tr>
<tr>
<td>Green resin and fat acids</td>
<td>1.22</td>
</tr>
<tr>
<td>Undecomposed biliary matter</td>
<td>0.60</td>
</tr>
<tr>
<td>Peculiar extractive matter (bubuline)</td>
<td>1.60</td>
</tr>
<tr>
<td>Albumen</td>
<td>0.40</td>
</tr>
<tr>
<td>Biliary resin</td>
<td>8.80</td>
</tr>
</tbody>
</table>

According to M. Kochlin's practical knowledge on the great scale, it consists of a modest fibrous vegetable substance, which is animalized, and forms about one-tenth of its weight; 2, of albumen; 3, of animal mucus; 4, of a substance similar to bile; 5, of muriate of soda, muriate and acetate of ammonia, phosphate of lime, and other salts; 6, of benzoin or musk.

Probably the hot water in which the calico-printer diffuses the dung exerts a powerful solvent action, and in proportion as the uncombined mordant floats in the bath it is precipitated by the albumen, the animal mucus, and the ammoniacal salts; but there is reason to think that the fibrous matter in part animalized or covered with animal matter, plays here the principal part; for the great affinity of this substance for the albuminous salts is well known.

It would appear that the principal function of dunning is to hinder the uncombined mordant diffused in the dung bath from attaching itself to the unmodified portion of the cloth, as already observed; for if we merely wished to obviate the thickening stuffs, or to complete by the removal of acetic acid the combination of the albuminous base with the goods, dung would not be required, for hot water would suffice. In fact, we may observe, that in such cases the first pieces passed through the boiler are fit for dyeing; but when a certain number have been passed through, the mordant now dissolved in the water is attracted to the white portions of the cloth, while the free acid impoverishes the mordanted parts; so that they cannot afford good dyes, and the blank spaces are tarnished.

It seems to be ascertained that the mordant applied to the cloth does not combine entirely with it during the dying; that this combination is more or less perfect according to the strength of the mordants, and the circumstances of the dying; that the operation of dunning, or passing through hot water, completes the combination of the cloth with the albuminous base now insoluble in water; that this base may still contain a very minute quantity of acetic acid or sulphate of alumina; that a long churning in water impoverishes the mordant but a little; and that even then the liquid does not contain any perceptible quantity of acetate or sulphate of alumina.

A very able and learned memoir upon this subject, by M. Penot, Professor of Chemistry, appeared in the Bulletin of the Society of Mulhausen, in October, 1854, with an ingenuous commentary upon it, under the title of a Report by M. Camille Kochlin, in March, 1835.

Experience has proved that dunning is one of the most important steps in the process of calico printing, and that if it be not well performed the dyeing is good for nothing. Before we can assign its peculiar function to the dung in this case, we must know its composition. Fresh cow's dung is commonly neutral when tested by litmus paper; but sometimes it is slightly alkaline, owing, probably, to some peculiarity in the food of the animal.

The total constituents of 100 parts of cow dung are as follows: Water, 69.38; bitter matter, 0.74; sweet substance, 0.92; chlorophyll, 0.28; albumine, 0.43; muriate of soda, 0.08; sulphate of potash, 0.06; sulphate of lime, 0.28; carbonate of lime, 0.24; phosphate of lime, 0.46; carbonate of iron, 0.09; woody fibre, 26.39; silica, 0.14; loss, 0.14.

In dunning calicoes, the excess of uncombined mordant is in part attracted by the soluble matters of the cow's dung, and forms an insoluble precipitate, which has no affinity for the cloth, especially in presence of the insoluble part of the dung, which strongly attracts alumina. The most important part which that insoluble matter plays, is to seize the excess of the mordants, in proportion as they are dissolved by the water of the bath, and thus to render their reaction upon the cloth impossible. It is only in the deposit, therefore, that the matters carried off from the cloth by the dung are to be found.

M. Camille Kochlin ascribes the action of cow dung chiefly to its albuminous constituent combining with the alumina and iron, of the acetics of these bases dissolved by the hot water of the bath. The acids consequently set free soon become evident by the test of litmus paper, after a few pieces are passed through, and require to be got rid of either by a fresh bath or by adding chalk to the old one. The dung thus serves also to fix the bases on the cloth, when used in moderation. It exercises likewise a deoxidizing power on the iron mordant, and restores it to a state more fit to combine with coloring matter. See DRUNING.
CALICO PRINTING.

The use of cow dung is open to some objections, amongst which are its giving a certain amount of greenish coloring matter to the white mordants, and its being apt to vary in its constituents from differences in the food of the animals, their health, &c.; the method of using substitutes for it being now well known, and better colors and whites being more easily obtained from them than with dung, it is probable that cow dung will in a short time cease to be used in calico printing processes. The dunging operation ought to be a definite chemical decomposition, which cannot be the case with a variable substance like dung. The substitutions for dung in use are:

1. Phosphate of soda and lime.
2. Arsenate of soda.
3. Arsenite of soda.
4. Silicate of soda.
5. Silicate of lime.

Each of these has its peculiar virtues, and the printer determines for himself which is best adapted for his styles. The first was patented by John Mercer, about 1842, and is made by calcining bones, then decomposing them with sulphuric acid, filtering out the sulphate of lime, and, to the clear superphosphate of lime, adding carbonate of soda till slightly alkaline; the resulting mixture of phosphate of soda and phosphate of lime is dried down to a powder; the use of arseniates formed part of the same patent. Arsenite of soda followed as a matter of course, though not so safe in use as phosphates and arsenates. Silicate of soda was suggested by Adolph Schlipeper, of Elberfeld, and patented by Jäger in 1852. It is the ordinary soluble glass dissolved in water. It is open to the objection of being too alkaline, and requires care in the use. The silicate of lime was suggested by Higgins with a view to remove this objection. The silicate of lime is formed in the dung cistern, by mixing silicate of soda and muriate of lime, when sparingly soluble silicate of lime is formed; the quantity in solution at one time being never so much as to be dangerous, and fresh portions being dissolved as wanted. Dunging sales, or liquors, are now made by the manufacturing chemist, containing various mixtures, arseniates, phosphates, arsenuates, &c., which are adopted for every variety of dunging. Great economy of time and material result from the use of these dung substitutes. In some of the largest print works, instead of, as with dung, running off the spent-dung cistern after passing through from 100 to 200 pieces, and having to fill again, and heat to the proper temperature, it is found possible to run pieces through the same cistern charged with substitute, at the rate of a piece per minute half a day, and with light goods a whole day—before letting off, of course occasionally adding some of the substitute, to make up for that saturated by the mordants. The dunging process is always performed twice: the first time in a cistern with rollers; and the second, in a beek similar to a dye beek, washing well between. The first is called fly-dunging; the other, second dunging.

The manner of immersing the goods, or passing them through the dung bath, is an important circumstance. They should be properly extended and free from folds, which is secured by a series of cylinders.

The fly-dung cistern is from 10 to 12 feet long, 41/2 feet wide, and 6 or 8 feet deep. The piece passes alternately over the upper rollers and under rollers near the bottom. There are two main squeezing rollers at one end, which draw the cloth through between them. The immersion should take place as fast as possible; for the moment the hot water penetrates the mordanted cloth, the acetic acid quits it, and, therefore, if the immersion was made slowly, or one ply after another, the acid, as well as the uncombined mordant, become free, would spread their influence, and would have time to dissolve the alumino-subsalt now combined with the cloth, whence inequalities and impoverishment of the colors would ensue.

The fly-dung cistern should be set with about 30 gallons of dung to 1,000 gallons of water; or, to the same quantity, 3 or 4 gallons of dung-substitute liquor; a little chalk is added, to make the cistern slightly milky. The heat varies for different styles—from 150° F. to boil. Where there is acid discharge or resist, and the colors are heavy, fly-dunging at boil is necessary, to enable the acid to cut properly through the color; the nearer to 150° F. that the bath will give good whites at, the better will be the subsequent dyed color. With cow dung, an excess of it is injurious, both to white and color; but with a tolerably neutral substitute, excess does no harm. The pieces should run at the rate of 50 to 60 per hour. On leaving the cistern, they are well winced in water, and washed, and are then second dunged, which is generally performed in a beek similar to a dye beek, which will be found described farther on. This beek is set with about 1 quart of dung-substitute liquor, or 12 gallons of dung to 250 gallons. From 12 to 24 pieces are put in together, and made to revolve over a reel for about 20 minutes or half an hour, the heat being about 150° F. They are then well washed, and are ready for dying. This second dunging is principally for the purpose of removing the thickening substance from the cloth, and it should feel quite soft when well done. An improved method of dunging adopted by some extensive firms consists in arranging a fly-dung cistern, a wince pit, a machine similar to the laundress’s washing machine, and containing the second dunging solution and one of the dye-house.
washing machines all in a line; the pieces, being then stitched end to end, are drawn through the series; first, extended and free from folds, through the fly-dung cistern; thence dropping into water in the pit; from that being worked spirally from end to end of the second dunging vessel, which runs at such a speed that one piece is about 15 minutes in traversing it; from that into a water pit again, and finally, spirally, through the washing machine, when they are ready for dyeing. By this arrangement the process is a continuous one, and little labor is required. The drawing rollers on the fly-dung cistern are worked by a strap from a shaft. On the thorough cleansing from loosely attached mordant, and especially thickening, depends a good deal of the success of the dyeing, and this process is one that requires to be carefully attended to.

The washing processes in the dye house have undergone great modifications within the last few years. Formerly, in washing, the old dash wheels were exclusively employed, but now are considered far too slow, and expensive in labor, and are nearly abolished, being substituted by various washing machines. A great number of machines have been invented, which all have their admirers. Three, which have been found very efficacious, are here given.

Fig. 129 is a perspective view, and fig. 130 a section of the machine patented by Mather and Platt. The pieces, fastened end to end, are run spirally through the machine, being subjected to the action of the beams or beaters d d, whilst lying in loose folds on the large wooden roller c.
Fig. 131 is a machine patented by Whitaker, and possesses the merit of great simplicity with comparatively small first cost, together with great efficiency. The invention consists of a peculiar arrangement of the material to be washed, by which, instead of it moving in one continuous direction, it is made to cross in its traverse; and by one part being in constant contact with another part, a powerful rubbing action is continually kept up, thereby washing or cleansing the cloth or material more effectually than can be done by the usual method of merely passing it between presser rollers.

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Fig. 133 represents the machine patented by Mr. David Crawford of the Barrowfield Printing Works. It is said to answer well for all sorts of fabrics, the finest muslins not being torn by this, as is the case with most washing machines. The machine consists of a rectangular frame, fitted up with rollers, dashboards, a dusting frame and driving gearing. The frame is divided into a series of stories or flats, one above another, like the floors of a house, each flat having a dashboard or a fixed platform divided down the centre, towards which division-line each half inclines downwards. The goods in a continuous length-like form are passed first of all round a taking-in roller, which directs each flat to the horizontal roller of considerable diameter, which runs in bearings at one side or end of the lowest of the series; the fabric passes round this roller, and there proceeds horizontally along and through the flat at that level, passing in its way through a vertical traversing frame, which works between the contiguous edges of the platforms or dashboards of all the flats where the boards are divided as before explained. In the centre, at the opposite end of the frame, there is a corresponding roller, round which the fabric passes, returning through the flat and through the vertical traversing frame to the first roller; the fabric passes again round this roller and again through the flat, and so on until the required number of crossings and re-crossings has been completed. The rollers are geared together so as to be driven simultaneously to carry the fabric along back and forward over these rollers and through the flats, whilst jets of water or other fluids are allowed to fall upon the fabric in its passage, and whilst the vertical traversing frame dashes the cloths with rapidity and severity upon the dashboards beneath; the traversing frame being worked by an overhead crank, or by any other reciprocator. As the cleansing liquid falls down it is received upon the dashboards beneath, and until it pours off at the centre; the striking action causes the liquid to be well forced into the fabric. When the water falls away at the centre it is received by a bottom duct and conveyed away to a bottom side-chamber, into which chamber the fabric, as primarily washed in the bottom flat, is first of all delivered from its rollers to the next flat on the series, where it is treated in a precisely similar manner; and this routine is continued throughout the whole of the flats until the fabric finally emerges from the top of one of the series in its completely cleansed condition. Each flat is supplied with jets of water, and it is obvious that as the fabrics pass through and beneath these jets, and violently struck upon the dashboards, a most powerful washing and cleansing action is secured; provision is made for varying the length of traverse of the vertical dashing frame and the rapidity of its traverses.

Fig. 133 on the drawings is a sectional elevation, and Fig. 134 is an end view corresponding, as looking on the driving gear, and the taking in and delivering movements. The two cast-iron side standards, \(a\), form the main frame. These standards carry internal bracket flanges for supporting the four dashboard floors \(c\). All the driving movements are actuated from a bottom horizontal shaft, carrying a bevel wheel \(q\), in gear with a corresponding wheel \(r\), fast on the lower end of a vertical shaft \(s\). This shaft, by means of the two pairs of bevel wheels \(v\), drives the two large end rollers \(x\), carried in end bearings external to the main framing. The lower end of the shaft rests in a footstep bearing on the floor, whilst the upper end is supported in a collar bearing, carried by brackets \(y\), bolted to the frame. At this part, a third pair of bevel wheels, \(r\), forms the driving communication between the shaft and the end conical roller pulley \(l\), working the dashing movement. All the stories or dashboards of the machine are plentifully supplied with water by the pipe \(p\), having a regulating stop-cock at its upper or lower branch. From this main pipe, cross
branches p, pass into and through all the divisions discharging the water by the jets upon the goods passing through the machine. A guide ring is attached to the ceiling of the workshop v, for the passing through of the goods n. From this ring, the line of goods passes in the direction of the arrow, down and round a guide roller arrangement, so as to be directed through the water in the small bottom chamber z. On leaving this chamber the fabric passes through a deep eye in the end boarding of the machine, and thus reaches the lowest division of the series. As it continues its course it passes between the lowest pair of rollers or bars r, of the vertical traversing frame f, which gives the necessary dashing action, then proceeds, guided by the pin o round the bottom back roller n, corresponding to the lowest of the front rollers x. On running this roller, the fabric repeats the circuit already described three or more times, as indicated by the turns upon the roller, in the view of fig. 2. After the completion of this traverse, the line of fabric ascends, as shown by the arrow being drawn out between the nipping roller p and the bottom roller n. The fabric again ascends for the last time and passes through the third and fourth divisions, being delivered in a cleansed condition at g. The dashing action, as already explained, is worked from the conical pulley j, the spindle of which runs in pedestal bearings immediately above the centre of the machine. A sliding rod, with a double strap fork m, is fitted up for enabling the attendant to set the drawing belt k, at any part of the conical pulley, so as to vary the rate of revolution of the driving pulley t. The spindle of the pulley j carries at each end an adjustable disc crank l, the face slots of these discs having crank stud-pins set in them for working the upper ends of the pendant connecting rods h. The lower ends of these rods are similarly jointed to stud c upon the opposite edges of the traversing dashing frame f. These studs work through vertical slots in the main standards, and as the disc crank l revolves at a rapid rate, it follows that the corresponding rapid traverse of the dashing frame energetically dashes the lines of fabric passing between its rollers upon the several dashboards of the machine. The cleansing water falling from the several jets, is conducted from flat to flat by conductors y, thoroughly washes the goods, whilst this is going on, and it finally falls through the central openings in the dashboards, and is received into the bottom central trough, whence it flows away by the duct, and is delivered into the chamber z. The lever x in connection with pulley r is to enable the attendant to raise up pulley r in threading the machine. This machine is beautifully adapted for bleaching purposes, as from the peculiarity of its action it answers as a

perfect Bleaching Machine in itself. The slots, grooves in the disc cranks, afford a ready means of varying the length of the traverse of the dashing frame; and this adjustment, coupled with that of the rate of revolution of the central conical roller, affords the greatest possible nicety of adjustment of the powers of the machine, which the manufacturer, bleacher, or finisher can ever require, either for light or heavy goods.
Up to this point there is scarcely any difference in the operations on pieces destined for styles 1 a, b, &c., and 2. Those intended for dyeing with madder are printed in stronger colors than those for dyeing with garance, since the soaping process reduces the strength of color considerably, and garance colors undergo no severe treatment after dyeing. The general process of dyeing is thus performed:—

Fig. 135 represents a front elevation of a pair of dye becks, with automatic winch reel, and fig. 136 is an end elevation of one of them. The drawing is kindly supplied by Messrs. Mather and Platt, of Salford. A a is a cast-iron cistern, 8 feet long by 4 feet deep by 3 feet wide, with curved bottom; brackets b b are cast on the ends to support the cistern on
the stone foundation. The beck is fixed over a channel \( c \), which communicates with the system of drains which carry away the waste liquors into the river. There are two holes in the curved bottom—one at each end—which, when the beck is in use, are stopped with movable plugs; one of these holes communicates direct with the drain and the other with a trough \( d \), which communicates with a pit outside the dye-house, and where the spent madder can be run for the purpose of making into garanceux. \( e \) is a water pipe, with a branch into each beck, with a screw tap attached; \( f \) is a main steam pipe, which divides into the branches \( g \), furnished with valves at \( h \); the pipes \( g \) subdivide in branches \( i \), one of which goes down each end of the dye beck, the perforated pipe \( k \), which traverses the beck from end to end, connecting them; a perforated iron diaphragm is placed across the beck from end to end; above this is a strong rod \( m \), from end to end, carrying pieces \( n \) projecting at right angles from it. Bolted on the ends of the dye beck is the framework \( o \), which carries the bearings of the shaft \( q \) of the winch reel; keyed on the shaft are three sets of cast-iron arms \( x \), which terminate in forks, in which fit the spars \( s \); the reel is boarded between the spars, as at \( t \). The framework \( o \) of the two dye becks is connected by the piece \( u \), which carries the bearings of the short shaft \( v \), on which is keyed one of a pair of mitre wheels \( w \); there are sliding catch boxes \( x x \) on this shaft, which revolve with it; there are corresponding catch boxes keyed on the ends of the shaft \( q \); the connecting piece \( t \) carries also the pillar \( v \), which carries the bearings of the vertical shafts \( y \), and also of the horizontal shaft \( z \); keyed on the shafts \( y \) and \( z \) are bevel wheels \( a \) and \( b \), and at the bottom of shaft \( y \), the mitre wheel \( w \). Permanent motion being given the shaft \( v \), by this gearing, either of the reels can be put in motion or stopped by the catch boxes \( x x \), worked by lever handles, in or out of the catch boxes on the ends of the reels. In working the becks, two pieces are knotted end to end, and each length passed over the reel down between two of the studs \( s \), under the steam pipe \( k \), up behind the diaphragm \( l \), being then knotted together so as to form an endless web, the bulk of which lies on the bottom of the beck. The drawing shows a beck adapted for 15 lengths of 2 pieces each, or 30 pieces. About 200 gallons of water are put in the beck before the pieces are put in; and, after the pieces, the dye stuff is added, the reel set in motion, and the steam gently turned on; from the steam going in at each end, the beck is uniformly heated; the heat is then gradually raised to boil, generally in about two hours, the pieces continually revolving with the reel so as to bring each portion successively into the air, agitating the dyeing materials at the same time. When the dyeing is finished, the steam is shut off, the knots untied, and the pieces pulled over into a pit of water surrounded by a winch reel, which is always placed behind every dye beck. After wincing in this, the pieces are fastened together again, and put through the washing machine two or three times; they then are ready for the subsequent operations. Madder goods, on issuing from the dye beck, are far from possessing the beauty that they afterwards show, the colors are dull and heavy, and the white part stained with a reddish shade; various clearings are required, in which soap plays a principal part. Garancined goods show pretty nearly the color they are intended to be; but as the white is also stained, a peculiar clearing is given them which will be described further on. Madier goods are cleared with soap in a beck similar to a dye beck. They receive generically two soaping of about half an hour, with from \( \frac{1}{2} \) to \( \frac{1}{4} \) lb. of soap per piece each time, washing between. If the white is not sufficiently good, the pieces are spread out on the grass for a day or two, and are afterwards winced in hot water to which a little solution of chloride of lime or soda is added. They are then washed and dried. Chinutz dye is dyed with from 1 lb. to 3 lbs. madder per piece of 30 yards, according to the pattern; generally, a little chalk is added, and if there is no purple in the pattern, a little sumac, which is found to economize madder, but will not do where there is purple, the shade of which it deadens. Pieces of any style, after undergoing the final process, are passed through a pair of squeezing rollers, or put in the hydro-extractor, when the moisture is driven out by centrifugal force, (see Hydro-extractor,) they are then dried on the cylinder drying machine.
Plate Purple is a style composed of black and one or more shades of purple only, and requires a little different treatment. Print in black No. 4, dark purple to shade No. 27 and acid, say No. 35, cover pad in pale purple, No. 50, age. Fly d已经成为 at 170° F., second d已经成为 at 165° F., half an hour; wash and dye with ground Turkey madder root, giving 1% of its weight in chalk, and 3 quarts of bone size to the beck; bring to 175° F. in 2 hours, and keep at 175° F., half an hour; wash well and soap 15 pieces, 1/2 yds., half an hour at boil with 5 lbs. soap to 15 pieces; wash well and wince 5 minutes at 110° F. with 2 quarts chloride of lime liquor at 8° F. to 300 gallons; wash and soap again at boil half an hour with 3 lbs. soap to 15 pieces; wash and wince 5 minutes in 4 quarts chloride of lime at 8° F. and 2 lbs. carbonate of soda crystals to 200 gallons water; at 160° F. well wash and dry.

In this style, as in any where there is severe soaping, it is necessary to give a slight excess of madder in the dye, so as to ensure perfect adhesion—if this is not done, the color speedily degrades, and becomes impoverished. It may be observed here, that the style plates are such as formerly were printed by the plate or flat press, and are generally small patterns, with padded or well covered grounds, the colors being few, and frequently only different shades of one color.

Plate Pinks or Swiss Pinks—a style imported from Switzerland, consisting of various shades of red and delicate pinks, produced as follows:—Print in No. 6 with second or third shades, as No. 7—acid No. 34 may be also be printed, and a very pale shade of red covered, aged two or three days, dunned at 160° F.—if dungen substitutive is used, care must be taken to use one that is not caustic from free alkali; the dyeing must be done with the finest quality of French or Turkey madder. The pieces must have sufficient madder allowed to over dye them, or dye a heavy brownish red. For a full plate pink on 1/4 cloth, from 4 to 6 lbs. of French madder will be required. About 5 per cent. of chalk may be added to the dye where the water is soft. The heat should be raised to 150° F. in 2 hours, and kept at that heat half an hour. It is necessary to keep the heat low in dyeing French pinks, to prevent the impurities from fixing on the mordants, as only the very finest portion of the coloring matter must be fixed—after dyeing, the pieces are well washed and soaped with about half a pound of soap per piece in a beck at 150° F. for half an hour, then are then washed and entered in a beck with cold water, to which has been added sufficient oxymuriate of tin or sulphurous acid to make faintly sour, a little steam is turned on, and the heat raised to about 120° F. in half an hour; the colors which on entering the beck were full shades of red, gradually assume an orange tint, and when of a bright orange color, the pieces are taken out, and wince in water. This operation, termed cutting, is the one that decides the depth of tint in the finished piece. The longer the pieces are kept in the beck, and the greater the heat, the paler and more delicate the shade of pink obtained. After this treatment they are put in a beck with soap, and boiled for an hour, taken out, washed well, and put in a strong pan charged with soap and water, the lid screwed down, and boiled at a pressure of two atmospheres, either by direct fire or high-pressure steam, for two or three hours, then taken out, washed, and put in a beck with water at 100° F., charged with a little hypochlorite of soda: they stay in this about ten minutes, and are then washed and dried. In some print works, after the high pressure boil, the pieces are spread out on the grass for a night or two, and then cleared in hypochlorite, &c. The use of the acid here is not very clear, it probably completely purifies the color from iron which may have been in the mordant, but it also seems to render the combination of alumina, tin, lime, coloring matter, and fat acid a definite one by removing a small quantity of the mordant. The French chemists assert, that, after the final process, a definite atomic compound of lime and alumina, coloring matter, and fat acid remains.

The quality of the soap used by printers is of great importance. It is made for them specially from palm oil, and requires to be as neutral an oleo-stearate as possible; an alkaline soap like domestic soap would impoverish and degrade the shades.

The soaping process has a twofold action:—
To clear the white by decomposing the compound of lime and coloring matter which forms the stain; this it does by double decomposition, forming oleo-stearate of lime, which dissolves or forms an emulsion with the excess of soap; and a compound of soda and coloring matter, which dissolves. In its action on the dyed parts, it probably first removes resins and other impurities which are loosely held by the mordant, and secondly gives up a portion of its fat acid to the dyed parts—the resinous acids or possibly phosphoric acid from the dyed parts, by combining with the soda, setting free fat acid for this purpose.

Second Style: Garancin.

Almost all the madder styles are imitated by dyeing with garancin, a concentrated preparation of madder (see Madder) which dyes fine brilliant colors at once, not requiring to be soaped to develop the shades, but not possessing the extreme solidity of madder color. Garancin dyeing is the most economical way of using madder, since more coloring matter is obtained in this way than by using madder direct, and consequently garancin is principally
used for full heavy colors, which, if dyed with madder and soaped, would be, to a certain extent, abraded, and not stand so finely on the surface of the cloth. Chocolate grounds, black, red, and chocolate, with brown or drab, dark purple plates, black and scarlet ground, are thus dyed; in short, wherever the pattern is very full, and cheapness essential, garancin is resorted to. The colors or marquizes for garancin are usually about two-thirds of the strength of similar colors for madder, (see the list of colors,) the ageing and dunging, &c. are the same as for madder; the dyeing is performed in the same manner, using from one-fourth to one-third the quantity that would be used of madder. A little chalk is also added where the water is soft; and the dyeing is commenced at 110° F., and carried to 180° F., or 190° F. in two hours; then got out and well washed and rinsed in water at 140° F., in a beck, for 10 minutes, then squeezed and dried. The white is always staled a little, though not to the same extent as in maddered goods, and this slight stain is removed by a process peculiar to garancin goods. In front of an ordinary cylinder drying machine, is placed a padding apparatus, and between it and the drying machine is placed a chest provided with a few rollers at top and bottom; this chest is covered by a lid, which has at each end a slit, by which the piece enters and issues; a perforated steam pipe at the bottom of the chest allows steam to blow freely in. The padding machine is charged with solution of hypochlorite of lime, at from $\frac{1}{2}$ to 2° Traddock's hydrometer, according to the depth of the stain on the white; the pieces are padded in this liquor, squeezed out by the bowls, and then run into the steaming chest, which is of such a size, that any given point on the piece is about $\frac{1}{2}$ minute in passing through it; on leaving this chest, the pieces pass through water, or water is spirited on from a perforated pipe; after again passing through squeezing rollers, they proceed on to the cylinders of the drying machine, on leaving which the white is found to be perfectly bleached and the colors brightened.

There are several varieties of garancin, each adapted to particular styles. For dark full black, chocolate, and red, with brown or drab, and where there is no purple, a garancin termed chocolate garancin, made from the commonest descriptions of madder, answers very well, and this class of goods is usually dyed with chocolate garancin, assisted by small quantities of sumac, quercitron bark, and peachwood, which additions give full rich shades. Where there is purple, none of these adjuncts can be used, and the garancin requires to be made from a superior description of madder. Within the last three or four years, great improvements in the manufacture of purple garancins have been made. The Alizarin, patented by Pincoff and Schunk, has the property of dyeing at once purples as pure as the finest soaped madder shades; it has the disadvantage of not dyeing well black and reds, and when these colors are freely introduced along with purple, an admixture of ordinary purple garancin is required, the general effect being still very good, but the purple not quite so fine. The garancin patented by Higgins dye very good purple, with black, chocolate, and red also. Both these improved garancin stain the white grounds very little, and produce considerably faster work than the ordinary garancins; the goods may even be soaped to a considerable extent. A garancin that will bear as severe soaping as madder, or a method of so dyeing with garancin as to produce the same effect, is still a desideratum. When this can be accomplished, there will be an end of dyeing with madder, which will be considered a raw material, and be all manufactured into garancin.

Garancinex.—In ordinary madder dyeing, the madder can never be made to give up all its coloring matter; when all coloring matter soluble in water has been exhausted, there still remains about a quarter of the whole quantity, combined with lime, and mixed with the woody fibre. This madder is turned to account by converting it into garancin, or, as this preparation is called, garancinex. The spent madder is run off into a pit outside the dye-house, where it is mixed with a small quantity of sulphuric acid, to precipitate any coloring matter in solution. It is then allowed to drain dry; removed from the pit, it is boiled in a leaden vessel, with more sulphuric acid, for several hours, then washed on a filter till free from acid, and, after draining, is ready for use. It dyes to about one-third the strength of ordinary chocolate garancin, and is principally used for the commoner garancin styles. Mr. John Lightfoot, of Accrington, has patented an improvement in the ordinary process of making garancinexes. He recommends large vats to be provided, two or more in number, each sufficiently large to contain all the waste dyeing liquor produced in the dye-house in one day, and so arranged that the liquor runs from the dyebecks into them; at a certain point in the trough that conveys the liquor to the vats, is placed a lead cistern with a valve and perforated bottom; this cistern holds a regulated quantity of concentrated sulphuric acid, and whenever a dyebeck is let off and the liquor flowing down the trough, a quantity of acid, proportionate to the quantity of madder, is allowed to run down through the perforated bottom and mix with the hot liquor; the acidulated liquor then runs into the vat, a tightly fitting cover on which keeps the liquor hot. When the day's dyeing is done, the vat is left covered up all night; next day the lid is raised, and, by means of holes and pegs in the side of the vat, all the clear liquor is drained away, the vat filled anew with water stirred up, and, when settled, the clear drawn off again; this washing being repeated till all the acid is washed away, the garancinexes are then run on a filter to drain for use. The advan-
tages of this plan are, first, the saving of fuel, by economizing the heat of the waste liquor, and, secondly, the production of one-fourth more coloring matter.

Third Style: Reserved.

Madder or garancined goods are often left with white spots, as if from the leaves, &c., and when dyed these spaces are filled with various bright colors, such as green, blue, yellow, &c. These colors are the ordinary steam colors, described hereafter, and are fixed in the same manner.

Another way of combining madder or garancin colors with steam colors, is by blocking on the dyed object, generally groups of flowers, a reserved paste, (No. 39,) and when this is dry, covering by machine in small patterns with various shades of drab, olive, &c., (Nos. 5, 44, 46, &c,) which then are damped and dyed with quercitron bark, cochineal, madder, and bark, &c., &c. Where the paste has been applied, the colors underneath, or the white spots reserved, are unaffected by the covering color, and stand out clear surrounded by the covering color. In the white spaces reserved are now blocked steam colors, which are raised by steam, as described further on.

Fourth Style: Padded.

In this style the white cloth is mordanted all over by padding in red or iron liquor, or mixtures of them, drying in the padding flue; then a pattern is printed on in acid, and the usual mordanting and dyeing operations performed, the result being a dyed ground with a white pattern.

Fig. 137 represents a section of the padding flue used in mordanting to this style.

It consists of a long vaulted chamber, about 35 yards long by 5 yards, and 4 yards high, cut in two at nearly half its length, by 6 small arches built in an opposite direction to that of the chamber, the object of which is to preserve the principal arch from the action of the heat, and to hinder the dried pieces from being exposed, on coming to the higher part, to moisture and acids, which are disengaged in great abundance, and might condense there.

C C is a long furnace, the flue of which forms the bottom of the chamber; the top of the flue is covered with plates of cast-iron fitting one into another, and which can be heated to near red heat by the flame of the furnace. R is an arched passage, by which the interior of this store can be reached. H H are ventilating holes in the lateral wall, which can be opened and closed at will by means of the rod J, which is connected with sliding doors over the apertures. K K are cast-iron supports for turned copper rollers, which are fixed to the cross pieces Y Y, and serve to conduct the piece. L L are bars of iron which carry the fans m m, which are covered by gratings, and make about 500 turns per minute.

In front of this hot flue is placed all the apparatus necessary for padding the pieces, and moving them through the drying chambers. This movement is caused by pulleys n n driven from a prime mover.

The mordant liquor being put in the box of the padding machine, the pieces wound on a beam and placed above the machine are conducted through the box, then between the two lowest rollers above the box, from them through the liquors again, passing next through the highest rollers, and so into the flue, their course being easily traced by the arrows; on leaving the flue dry, they are wound on a beam, or plated down on the wooden platform behind the machine. The 3 rollers of the padding machine are made of brass, and are wrapped with a few folds of calico; the iron journals of them work in slots, the lowest one being at
the bottom of the slot working in brass bearings; a weighted lever presses the top roller in forcible contact with the others.

Padded goods, after printing in acid, are hung 2 or 3 days in the ageing room, dunged, and dyed a few figures. The following recipes are here given:

a. Clarid and white.—Pad in red liquor at 10° T, dry, cool, and pad again in same liquor, dry, cool, and print in acid No. 37, age 3 nights. Fly dund at boil, wash, second dund at 160° F, 1/2 hour, wash, dry, and singe, wash and dye 12 pieces 7 ft. 8 in. 30 yards with 18 lbs. ground peacock, 21 lbs. of French madder, 5 lbs. sumac, 5 lbs. prepared logwood, run the pieces in the beck cold for 20 minutes, and then bring to a boil in 1 hour and 10 minutes, boil 15 minutes, get out, rinse and wash, brum 10 minutes at boil in a beek with a few pounds of bran, rinse in a pit and brand again at boil, wash and dry.

Prepared Logwood is thus made.—Ground logwood is spread out on a floor, damped with water, and heaped up. It is then turned over once a day for a fortnight, and occasionally wetted, during which time it changes from a dull red to a bright scarlet. It is then ready for use. Some change, probably oxidation, has taken place, and the wood dyes further after this process.

b. Scarlet and white.—Padded and dunged as for claret; then 10 pieces dyed with 15 lbs. French madder, 15 lbs. Dutch crop madder, 7 lbs. peacock, 4 lbs. sumac, with 3 quarts bone size; bring to a boil in 21/2 hours, and boil a quarter of an hour; wash and brand.

c. Scarlet and yellow.—Proceed as for scarlet and white, but dye 10 pieces with 221/2 lbs. crop Dutch madder, 221/2 lbs. French madder, 71/2 lbs. sumac, wash, brand, and dry; then pad in red liquor at 10° T, age 2 nights, fly dund at 130° F; wash and warm water at 120° for 10 minutes, dye pieces with 20 lbs. quercitron bark, heat to 120° in 1 hour, keep at 120° 15 minutes, wash and dry.

d. Burgundy and white.—Pad, &c., as for claret: dye 10 pieces with 18 lbs. French madder, 15 lbs. peacock, 12 lbs. logwood, 5 lbs. sumac, 4 quarts glue. Heat to boil in 13 hours, boil a quarter of an hour, wash and brand at boil 10 minutes, wash and dry.

e. Tyrian purple and white.—Pad, &c., as for claret: dye 10 pieces with 5 lbs. prepared logwood, 5 lbs. Dutch crop madder, and 7 lbs. peacock, 2 lbs. brand, and 3 quarts bone size. Bring to boil in 1 hours, boil a quarter of an hour, wash and brand at 150° 5 minutes with 1 lb. brand per piece, wash and dry.

f. Puce and white.—Pad, &c., as for claret: dye 12 pieces with 3 lbs. fine ground cochineal, 1 lb. ground galls, 4 lbs. prepared logwood, 3 lbs. peacock, heat to 170° in 1 hour and 20 minutes, keep at 170° 10 minutes, wash, brand at 160° 10 minutes; wash and dry.

g. Amber and white.—Pad, &c., as for claret: dye 10 pieces with 50 lbs. quercitron bark, 10 lbs. Dutch crop madder, 2 quarts bone size. Heat to 160° in 1 hour and 15 minutes, keep at 160° 15 minutes, wash, brand 10 minutes at 150°; wash and dry.

h. Peach and white.—Pad, &c., as for claret: dye 10 pieces with 2 lbs. ground cochineal, 2 lbs. peacock, 6 oz. logwood, heat to 140° in 11/2 hours, wash, brand at 140° 10 minutes; wash and dry.

i. Black and white.—Pad in red liquor at 20° T once; print in No. 30, age 3 nights, fly dund at boil, second dund at 140° 20 minutes, wash, dry, and singe; wash and dye 10 pieces with 60 lbs. prepared logwood, 4 gallons of bone size, and 6 oz. carbonate of soda crystals, heat to boil in 1 hour and 10 minutes; wash well and dry.

j. Olive, drabs, &c., with white.—A great variety of shades may be obtained by varying the merchant. For drabs, pad in iron liquor diluted about 10 times, according to the shade wanted, and dye in bark, or bark and logwood. For olives, pad in mixtures of red liquor and iron liquor, diluted, and dye in bark, or bark and logwood. The acid used may be No. 33.

l. Back dyeing.—Dye 10 pieces with 25 lbs. bark, and 3 quarts bone size; heat to 190° in 11/2 hours, and keep at 190° 10 minutes, wash and brand at 160° 10 minutes; wash and dry.

m. Bark and Logwood dyeing.—Dye 10 pieces with 20 lbs. bark, and 30 oz. prepared logwood, with 3 quarts bone size; heat as in bark dyeing.

Fifth Style: Indigo.

The indigo dye-house is always on the ground floor of a building, and is fitted up with a number of stone vats let into the ground. There are generally several rows of these vats, about 3 feet apart. They are about 8 feet long by 4 feet wide, and 8 to 10 feet deep. Some of them have steam pipes inserted, which go to near the bottom, so that they can be heated when necessary. There are about 10 vats in a row.

a. Blue and white.—The simplest form of blue styles is blue and white; dark blue ground with white figures. The cloth is printed in one of the following reserve pastes:

No 65. Reserve paste for Black.—3 lbs. sulphate of copper, dissolved in 1 gallon of water, 15 lbs. pipe-clay, heat up with some of the liquor; 1 gallon of thick gum Sonegal solution, and 1 quart of nitrate of copper at 80° T.
No. 66. Reserve paste for Machine.—2½ lbs. sulphate of copper, 1 gallon of water, thickened with 9 lbs. flour, and 2 lbs. dark British gum.

No. 67. Reserve paste for Machine.—5 lbs. sulphate of copper, 2 lbs. white acetate of lead, 2 gallons water, dissolve and thicken the clear with 3 lbs. flour and 2 lbs. pale British gum; when cold, add half a pint of nitrate of copper at 80° T., to every 2 gallons of color.

No. 68. Reserve paste for Machine.—4 gallons boiling water, 16 lbs. of sulphate of copper, 8 lbs. white acetate of lead, let settle and pour off the clear liquor; thicken 2 gallons of this with 8 lbs. of flour, and 4 lbs. pale British gum. When boiled, add 4 lbs. sulphate of zinc, and dissolve. The foregoing are all to resist deep shades of blue, for light shades of blue dipping any of the following:

No. 69. Mild paste for Block.—25 lbs. dark British gum, 15 quarts of water, boil 10 minutes, and add 7½ lbs. soft soap; stir well in, and, when mixed, add 20 lbs. sulphate of zinc, stir well in, and add 10 lbs. pipe-clay, beaten up to 7½ quarts of water, and 7½ gills of nitrate of copper at 80° T. Mix all well together.

No. 70. Mild paste for Machine.—8 lbs. dark British gum; 3½ quarts water; boil and add 2 lbs. soft soap, cool, and add 6 lbs. sulphate of zinc dissolved in 2 quarts of boiling water and 1 quart of nitrate of copper at 80° T.

After printing in one of these reserves, hang in a rather humid atmosphere for 2 days, and then dip blue.

Indigo for use in the dye-house is ground with water to a fine pulp; a series of cast-iron mills with curved bottoms, are arranged in a line: one or two iron rollers are moved backwards and forwards on the curved bottom in each mill by an upright rod, which is furnished with a roller at the bottom, and is connected with a horizontal rod worked by an eccentric. Indigo, and a certain quantity of water are left in these mills several days, till the pulp is perfectly smooth. The method of blue dipping is as follows:

In a line of ten vats, the first one is set with lime; as—

(No. 1.) 1,000 gallons water, 250 lbs. of hydrate of lime, or limeashed to a dry powder; when used, it is well raked up.

The indigo vats vary according to the style of work; for deep blue and white, or blue and yellow, or orange, the following is a good one:

(No. 2.) 1,000 gallons water, 50 lbs. indigo previously pulped, 160 lbs. copperas, and 170 lbs. lime; dissolve the copperas in the water, then add the indigo, stir well up, and add the lime, previously riddled to separate small stones. Take up every two hours for two days, and let settle clear. The clear liquor, when taken up in a glass, must have a deep yellow color, be perfectly transparent, and be immediately covered with a pellicle of regenerated indigo when exposed to the air. Eight or nine vats are all set alike.

The pieces to be dipped are hooked backwards and forwards on a rectangular frame which just fits the vats, so that the cloth can be immersed, but still not so deep as to touch the sediment of the vats. The process is thus performed:—The lime vat No. 1 being stirred up, the frame which contains two pieces, is lowered down into it, so as to completely immerse the pieces; a gentle up and down movement is given by hand. The frame is allowed to stay 10 minutes in, is then lifted out, and supported over the vat by rods put across. After draining here a few minutes, it is then removed and immersed in vat No. 2, or the first indigo vat. It stays here seven minutes, is lifted out, and drained as before over the vat 8 minutes, then removed to No. 3 vat, and so on, till it has gone through the whole series, or till the shade of blue is considered strong enough. After the last dip, the pieces are unhooked and wined in a pit of water, then wined about 10 minutes in a pit containing sulphuric acid at 6° T., washed well in the wheel, squeezed, and dried. In large dye-houses, there is an arrangement for collecting all the waste indigo which is washed off the pieces, by running all the water used into a vaulted chamber under the dye-house, where it passes from one compartment to another, gradually depositing the suspended indigo, which is periodically removed.

In heavy bodies of color, the paste sometimes slips, or the shapes become irregular; this is counteracted by using the first indigo vat raked up instead of clear. The vats are used till nearly exhausted, and then the clear liquor pumped off, to be used instead of water for setting fresh vats with.

IV. Blue and Yellow, or Orange.—Print in one of the reserve pastes, and yellow or orange color made as follows:—

No. 71. Chrome yellow for Machine.—2 gallons water, 20 lbs. sulphate copper, 20 lbs. nitrate of lead; dissolve, and beat up with 12 lbs. flour, and 2 gallons sulphate of lead bottoms; boil all together.

The sulphate of lead here is the by-product in making red mordant No. 8, and is drained to a thick paste.

No. 72. Orange.—Make a standard liquor by dissolving 24 lbs. white acetate of lead in 6 gallons water, and stirring 12 lbs. litharge in it till perfectly white, then let settle, and use the clear.

For the orange color take two gallons of this standard liquor, instead of the gallons of water in the above yellow color.
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Follow the same routine in dipping, &c., as for blue and white. After wining in sulphuric acid sours, wash well, and wince 10 minutes in bichromate of potash solution, 2 oz. per gallon at 100° F. Wash well, and wince in dilute muriatic acid at 3° T. containing 1 oz. oxalic acid per gallon, till the yellow is quite bright. The small quantity of chronic acid set free oxidizes and destroys the indigo that may be attached to the yellow color. After this souring, wash and dry.

If orange was printed instead of yellow, treat as for yellow; and after the murio-oxalate sour, wash, and raise orange in the following:—10 lbs. bichromate of potash, 300 gallons water, and sufficient slaked lime to make slightly milky; heat to 180° F., and wince the pieces in till the orange is full and bright; then take out, and wash well, and dry.

Other varieties of blue dyeing are:—

a. Two blues.
b. Two blues and white.
c. Two blues, white, and yellow or orange.
d. Dark blue and green.
e. Two blues and yellow.

For c and e a pale shade of blue is first given the cloth. The light blue vat is thus composed:—

(No. 5.) Light Blue Vat.—1,000 gallons water, 40 lbs. indigo, 70 lbs. copperas, 80 lbs. lime. For c. Dip light blue by three immersions, drawing well between; unhook, wince in water, then in sulphuric sours at 2° T.; wash, squeeze, and dry; then print on a reserve paste, and proceed as for dark blue and white; when finished, the pale blue having been protected by the reserve, has remained unaltered, all the rest being dark blue.

For d. Instead of reserve paste, print on yellow No. 71, and dip dark blue, sour and raise the yellow with bichromate of potash, omit the souring after chroming, and wash and dry. The yellow falling on the pale blue, makes a green.

For e. On white cloth print a subject in muriate of manganese, thickened with dark British gum, raise this as described under the head Bronze, dry and block in a reserve paste No. 63, then line and dip in the dark blue vat, letting stay in half an hour, remove, oxidize in the air, wash and sour with dilute muriatic acid, to which some muriate of tin has been added, wash and dry; where the peroxided of manganese has been is now dark blue, the ground pale blue with white object.

For f. Print as d, with yellow or orange in addition, and after the sulphuric sours, raise yellow or orange as before.

Dip light blue, print reserve paste and yellow, dip dark blue, wince, sour in sulphuric sours at 8° T., wince in water, chrome at 14° F., 10 minutes at 2° bichromate per gallon, wince, wash, and sour in the following:—7 lbs. oxalic acid, 3 lbs. strong sulphuric acid; dilute with water to standard 8° T.; wince till the yellow is bright, then wash and dry.

A style formerly very much in vogue, but now scarcely ever used, is the neutral or Lazulite style. It consists in combining mordants with reserves, and dipping blue; the colors throw off the blue, and are subsequently dyed with madder.

Neutrals are of two sorts:

1. Where reds and chocolate, or black, with resist white are printed, and dipped light blue, the resist white being only required to resist the blue.
2. Where the white is required to cut through the block, reds or chocolate in addition to the blue.

The following are examples of lazulite colors for the first variety:

No. 78. Black, (Machine).—4 quarts logwood liquor at 12° T., 1 quart gall liquor at 9° T., 1 quart red liquor at 20° T., 1 quart iron liquor at 24° T., 1 quart acetic acid, thicken with 3 lbs. flour, and 8 oz. starch; when boiled, add 1 pint Gallipoli oil, and 1 pint turpentine.

No. 74. Chocolate, (Machine).—3 quarts red liquor at 12° T., 1 quart iron liquor at 24° T., 1 lb. sulphate of copper, 24 oz. measure of nitrate of copper at 100° T., thicken with 2½ lbs. flour, and 1 lb. dark British gum.

No. 75. Chocolate, (Block).—5 quarts red liquor 12° T., 1 quart iron liquor 24° T., 2½ lbs. sulphate of copper, 36 oz. measure nitrate of copper at 100° T., 9 lbs. pipe-clay beat up well, and add 3 quarts of gum Senegal solution at 5 lbs. per gallon.

No. 76. Dark Resist Red, (Block).—2 quarts red liquor 12° T., 5½ oz. white acetic of lead, 4½ oz. sulphate of copper, dissolve, and beat up in it 6½ lbs. pipe-clay. Thicken separately 2 quarts red liquor at 12° T., with 12 oz. flour, and add, when boiling hot, 8 oz. of soft soap melted; mix well, add the pipe-clay mixture to this, and then 2 quarts red liquor at 2° T., thickened by dissolving gum Senegal in it. Stir the whole well together.

No. 77. Dark Resist Red, (Machine).—20 quarts nitrate of zinc at 36° B., 10 quarts water colored within a little peachwood, 12½ lbs. alum, 10 lbs. acetic of lead; dissolve all together with heat, stir till cool, thicken all together with 8 lbs. flour, and 13 lbs. dark British gum.

No. 78. Any shade of pale red is made for block by substituting the red liquor in color No. 76 by the mordant No. 8 reduced with water, according to the shade wanted.
No. 79. Any shade of pale red for machine is made by reducing the quantities of alum and acetate of lead in color No. 77.

The white reserve for this variety of neutrals is either of the mild pastes.

No. 80. Resist Brown.—2 gallons water, 24 lbs. catechu, 6 lbs. sal ammoniac, 1 gallon acetic acid; boil 15 minutes, and add 7½ gallons gum solution, 5 quarts nitrate of copper at 100° T.

Process.—The colors after printing are aged 3 days, then dipped light blue in the following blue vat.

(No. 4.) Neutral vat.—1,000 gallons water, 120 lbs. indigo, 125 lbs. copperas, 150 lbs. lime; rake up for two days, and let settle.

A frame with rollers top and bottom is lowered into this, and the pieces are run through; after leaving the vat, they are made to travel over rollers in the air for a sufficient distance to turn them blue; then into a pit of water, from that into a beck with cow dung and water, at 100° F., where they run 15 minutes, then washed and dyed madder or gara-

In the second variety of neutrals, the white is required to resist both mordants and blue, and is made thus:—

No. 81. Neutral White for Blocks.—7 quarts lime juice at 30° T., 1 quart water, 4½ lbs. sulphate of copper, 24 lbs. pipe-clay, 3½ quarts lime juice at 30° T., previously thickened with gum Senegal.

No. 82. Neutral White for Machine.—1 gallon lime juice at 42° T., 2 lbs. sulphate of copper, 32 oz. measure nitrate of copper at 100° T., thickened with 1½ lbs. starch.

The black is the ordinary madder or garancin black, Nos. 4 and 5 process.

The neutral white is first printed either by block or machine; if the latter, it cannot be in a pattern which should register accurately with the subsequent colors, as it must be dried perfectly before the other colors are printed, to avoid obtaining irregular shapes; the above reserve colors are then printed over the neutral white. Mild paste Nos. 71, 72 may also be printed along with the other colors, to reserve a white under the blue only. The subsequent process is the same as for the first variety.

After dyeing madder and garancin, and clearing with soap, &c., steam or spirit colors are generally blocked in. Parts of the yellow being made to fall over the blue form green.

Sixth Style: China Blues.

China blues, so called from the shade of blue resembling that on porcelain. In this style indigo is printed on, and made to penetrate and fix in the cloth by the subsequent process.

The color is made thus:—

No. 83. Standard China Blue.—In an indigo mill are put 45 lbs. indigo, 9 gallons iron liquor at 24° T., and 18 lbs. copperas, the whole ground till quite fine; then add 7½ gallons gum Senegal solution at 6 lbs. per gallon; grind an hour longer, take out and wash the mill with 6 quarts hot water, and add to the above.

No. 84. China blue gum.—Gum Senegal solution at 2 lbs. per gallon, containing 4 oz. copperas per gallon.

Colors are made by reducing the standard blue with the gum, according to the pattern and strength required. For instance, for two blues of medium shades:—

No. 85. Strong Blue.—1 volume standard, 2 volumes gum.

No. 86. Pale Blue.—1 volume standard, 10 volumes gum.

After printing, age one night, and raise as follows:—Two vats similar to indigo vats are set. No. 1, 1,000 gallons water, 500 lbs. slaked and dry lime.—No. 2, Solution of copperas at 5° T. In each vat is lowered a frame, which is provided with rollers at top and bottom, and in addition has a pair of bushes at each side of the frame, just above the surface of the liquor, in which are put beams, on which the pieces are wound alternately; the bearings of the beams being just above the surface of the liquor, allows the roll of pieces to be always half in and half out of the liquor.

The course of proceeding is this:—A beam containing two or three pieces stitched end to end is placed on a small frame at one side of vat No. 1, and by means of a cord previously threaded through the rollers in the vat, the pieces are slowly wound through the vat and on to a beam placed in the bearings at the opposite side of the vat, by means of a winch handle fitted on this beam; when the pieces have thus passed through vat No. 1, which is kept in a milky state all the time, the beam is lifted out and transferred to one of the pair of bearings in vat No. 2; the pieces are wound through this vat in the same manner; after this vat, they are removed to No. 1 vat, and worked through; this alternate liming and copperasing is continued till the pieces have been 4 times through each vat; then detach and wine in water; then put into sulphuric ours at 10° T., immersing completely in the liquor till the whites appear quite clear; then wash well, soak in fresh water at 120° F. a quarter of an hour with a 4 lb. soap per piece; wash again and in sulphuric ours at 1° T., at 110° F.; wash well and dry.

The various phenomena which occur in the dipping of China blues are not difficult of
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explanation with the lights of modern chemistry. We have, on the one hand, indigo and sulphate of iron alternately applied to the cloth; by dipping it into the lime, the blue is de-oxidized, because a film of the sulphate of iron is decomposed, and protoxide of iron comes forth to seize the oxygen of the indigo, to make it yellow-green, and soluble at the same time in lime water. Then, it penetrates into the heart of the fibres, and, on exposure to air, absorbs oxygen, so as to become insoluble, and fixed within their pores. On dipping the calico into the second vat of sulphate of iron, a layer of oxide is formed upon its whole surface, which oxide exercises an action only upon those parts that are covered with indigo, and deoxidizes a portion of it; thus rendering a second dose soluble by the intervention of the second dip in the lime bath. Hence we see that while these alternate transitions go on, the same series of deoxidization, solution, and re-oxidization recurs; causing a progressively increasing fixation of indigo within the fibres of the cotton.

Other indigo styles are dipped greens, blue with white discharge.

**Dipped Greens.**—There are 4 vats similar to indigo vats in a row, set with:

First: (No. 5.) *Light blue Vats for Greens.*—1,000 gallons water, 25 lbs. indigo, 45 lbs. copperas, 63 lbs. lime, dry slaked, 17 lbs. caustic soda, 24° T.; raked up 2 days, and settled clear.

Second: (No. 6.) *Yellow Vat for Greens.*—1,000 gallons water, 250 lbs. brown acetate of lead, 130 lbs. dry slaked lime; rake up till dissolved, and let settle clear.

Third: (No. 7.) Filled with water only.

Fourth: (No. 8.) Set with bichromate of potash at 4° T.

Each of these vats is mounted with a frame with rollers top and bottom; the pieces to be dipped are stretched end to end, and a length of cord being threaded through all the vats and fastened to a drawing roller at the end of the fourth, the pieces are drawn slowly through between the first and second; the cloth is made to travel several yards, so as to insure oxidation of the indigo before going into the lead vat; after leaving the fourth, they are detached, winced, and washed well.

For dipped greens, either white cloth is printed in patterns, as spots, &c., with mild paste, Nos. 69, 70; or a pattern previously printed in madder colors and dyed, &c., is covered up with mild paste by block; the cloth being now dipped green, the pattern or spots are reserved or untouched by the green: a very good effect is produced by dipping the Burgundy and acid No. 4, green, when the Burgundy part comes out a beautiful chocolate, and the white part green.

**Acid Discharge on Blue.**—A blue and white style, but which permits the most delicate pattern to be printed, which is not the case with the ordinary blue and white style. The cloth is first dipped a medium shade of blue, washed and dried, then padded in bichromate of potash at 6° T., and carefully dried in the shade, without artificial heat, and printed in the following color:

No. 88. *White Discharge, (Machine).*—8 lbs. light British gum, 1 gallon tartaric acid liquor 62° T., 1 gallon acetic acid 6° T.

No. 89. *White Discharge, (Block).*—The above color a little thinner.

No. 90. *Black for Turkey Red Ground.*—7 gallons logwood liquor at 8° T., 1 gallon pyrroligneous acid, 10 lbs. starch; boil and add 2 lbs. 10 oz. copperas; boil again and cool, then add 3½ pints permanganate of iron at 50° T., and 1 gallon of blue paste.

No. 91. *Blue Paste.*—(a) 6 lbs. copperas, 3 quarts water; dissolve. (b) 4 lbs. prussiate of potash, 1 gallon of water; dissolve. Mix a and b together, and add 1 quart standard red liquor No. 8, 1 quart nitric acid 60° T.

No. 92. *Yellow Discharge, (Block).*—1 gallon lime juice at 50° T., 4 lbs. tartaric acid, 4 lbs. nitrate of lead; dissolve, thicken with 6 lbs. pipe-clay, and 5 lbs. gum Senegal.

No. 93. *Yellow Discharge, (Machine).*—Thicken the above with ½ lb. starch, instead of the pipe-clay and gum.
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No. 94. Yellow Discharge, (Machine.)—1 gallon lime juice at 40° T., 42 lbs. tartaric acid, 5 lbs. white acetate of lead, 1½ lbs. starch; boil and cool, then add 1 lb. 14 oz. nitric acid at 60°.

No. 95. Blue Discharge, (Machine.)—(a) 1 lb. Prussian blue, 1 lb. oxalic acid, 1 quart hot water; grind well together, and leave to react on each other 24 hours; then (b) 3 quarts of water, 1½ lbs. starch; boil, and add 2 lbs. tartaric acid, and mix a and b together.

No. 96. Green Discharge, (Machine.)—½ gallons No. 95 blue, 1 gallon No. 94 yellow.

Process:—Print in any of the above colors, and as soon as dry from the machine, put through the decoloring vat.

(No. 97. Decoloring Vat.—1,000 gallons water, 1,000 lbs. chloride of lime; make well up, till quite smooth and free from lumps, then immerse a frame with rollers top and bottom, as in dipping greens, &c.; keep the vat stirred up so as to be milky, and run the pieces through at the rate of 1 piece of 28 yards in 3 minutes; on leaving the squeezing rollers, conduct into water and rinse, then wince 10 minutes in bichromate of potash at 4° T.; wash and wince in very dilute muriatic acid; wash well and dry.

In this style, such is the permanence of the Turkey red dye, that it is not much altered by passing through chloride of lime, whilst in the parts printed in the discharge colors, an instantaneous disengagement of chlorine takes place, which decolorizes the dyed ground, and where a mineral color or mordant formed part of the discharge, it is left in place of the red dye. This style was invented in 1811 by M. D. Koechlin, and patented in England by Mr. James Thompson, of Primrose, who printed immense quantities of it.

The Bandanna printing, being a business of itself, is more fully described in another place. (See Bandanna.)

Eighth Style: Steam Colors.

The printing of steam colors may be considered as a mode of dying at one operation, for in most cases one or more mordants are mixed with dye-wood decoctions, and printed on the cloth, the subsequent steaming causing the mordant to combine with the coloring matter, and both with the cloth. Steam colors, in some cases, are made so as to produce a fair color when printed on ordinary white calico; but much superior colors are produced by mordanting the cloth first, so as to fix peroxide of tin in the fiber; and as this is the almost universal rule, it is this sort of steam printing alone that will be described. Woolen fabrics, indeed, require a good preparation by tin, &c., before lively and substantial colors can be fixed on them by steam.

The following is the mode of preparing calicoes for steam colors:—

Pad the pieces stitched together, in a padding machine with wooden bowls, through a solution of stannate of soda at 10° T. twice over, letting them lie wet an hour between; immediately after padding the second time, run through a cistern with rollers, containing dilute sulphuric acid at 1½° to 3° T., thence into a pit of water, wince well, and run through a washing machine. It has been observed by Mr. James Chadwick, that if the cloth, with oxide of tin newly precipitated on it, is subjected to any severe washing, it loses a considerable quantity of oxide, so that no moro washing must be given at this stage than will remove the free sulphuric acid. It appears that the cloth, once dried with the oxide in it, does not part with the oxide again by severe washing. After washing, the pieces are unstitched, and put in the hydro-extractor, then dried gently over the steam cylinders, and are then ready for printing.

The following list of steam colors comprises the usual variety of shades printed on calico:—

No. 97. Steam Black, (Machine.)—1 gallon logwood liquor at 12° T., 1 quart gall liquor at 9° T., 1 quart mordant, 2 lbs. flour, 6 oz. starch; boil 10 minutes, and add ½ pint nitrate of iron.

Steam Black Mordant.—1 quart acetic acid, 13 quarts acetate of copper at 3° T., 1¼ quarts iron liquor at 24° T., 1 quart red liquor at 20° T.

No. 98. Chocolate, (Machine.)—5 gallons logwood liquor at 12° T., 2 gallons Japan liquor at 12° T., 1 gallon nitrate of alumina, 3½ gallons bary liquor at 12° T., 4 gallons water, 17 lbs. starch; boil, and add 8 oz. of carbonate of potash, ½ lbs. red prussiate.

No. 99. Dark Blue, (Machine.)—7 gallons water, 14 lbs. starch, 25 lbs. sal ammoniac; boil, and add whilst hot 12 lbs. yellow prussiate of potash in powder, 6 lbs. red prussiate of potash, 6 lbs. tartaric acid, and when nearly cold, 1 lb. sulphuric acid, (specific gravity 1.85.) 1 lb. oxalic acid dissolved in 2 quarts hot water, and 6 gallons prussiate of tin pulp.

No. 100. Dark Blue.—8 quarts water, 4 lbs. yellow prussiate of potash, 3 lbs. pale British gum; boil, and add 1 lb. bisulphate of potash, 2 lbs. muriate of ammonia, 8 oz. alum, 4 oz. oxalic acid, 4 oz. sulphuric acid at 170° T., 4 quarts tin pulp No. 103.

No. 101. Cinnamon.—1 quart cochineal liquor at 8° T., 1 quart logwood liquor at 8° T., 1 quart berry liquor at 10° T., 6 oz. alum, 4 oz. cream of tartar, 8 oz. starch; boil, and whilst warm add 3 oz. muriate-of-tin crystals.

No. 102. Orange.—12 lbs. annatto, 1 gallon caustic soda at 70° T., 5 gallons water;
boll 20 minutes, strain, and add 3 quarts red mordant No. 146, 6 lbs. alum; heat till clear, and add 4 gallons thick gum-substitute water.

No. 104. *Light Blue for Machine.*—1 gallon dark blue No. 99, 3 gallons 4-lb. gum-substitute water.

No. 105. *Green (Machine).*—7 gallons Persian-berry liquor at 12° T., 15 lbs. yellow prussiate of potash, 8 lbs. alum, 28 lbs. gum-substitute; boil, and add 2 lbs. muriate-of-tin crystals, 2 lbs. oxalic acid.

No. 106. *Pink, (Machine).*—4 gallons cochineal liquor at 6° T., 2 lbs. alum, 2 lbs. bitartrate of potash, 8 oz. oxalic acid, 4 gallons thick gum-Senegal water.

No. 107. *Purple, (Machine).*—2 gallons logwood liquor at 12° T., 12 oz. alum, 8 oz. red prussiate of potash, 1 oz. oxalic acid, 8 gallons gum-substitute water. If for block, add 12 gallons gum water instead of 8 gallons.

No. 108. *Dark Red, (Machine).*—8 quarts Sapan liquor at 12° T., 2 quarts bark liquor at 8° T., 2 quarts nitrate of alumina No. 109, 6½ lbs. starch, 1 lb. gum-substitute, 4 quarts water, 4 oz. chloride of potash, 12 oz. alum.

No. 109. *Nitrated of Alumina.*—3 gallons boiling water, 24 lbs. nitrate-of-lead crystals, 24 lbs. alum, 5 lbs. carbonate-of-soda crystals; let settle, and use the clear.

No. 110. *Blue Standard.*—1 gallon water, 12 oz. alum, 4½ oz. oxalic acid, 13 lbs. yellow prussiate of potash, 1 gallon gum-substitute water.

No. 111. *Lavender Liquor.*—2 gallons red liquor at 18° T., 6 lbs. ground logwood; let steep for 48 hours, then strain off the liquor.

No. 112. *Lavender.*—4 gallons lavender liquor No. 111, 4 gallons blue standard No. 110, from 24 to 48 gallons gum water, according to shade wanted.

No. 113. *Dracon.*—4 gallons lavender liquor, 4 gallons blue standard, 1 gallon bark liquor at 8° T., from 40 to 70 gallons gum water, according to shade wanted.

No. 114. *Stone.*—4 gallons lavender liquor No. 111, 6 gallons blue standard No. 110, 1 gallon bark liquor at 12° T., reduced same as drab.

No. 115. *Yellow.*—4 gallons berry liquor at 12° T., 1½ lb. alum.

No. 116. *Brown Standard.*—14 quarts bark liquor at 12° T., 3½ quarts Sapan liquor at 12° T., 1½ quarts logwood liquor at 12° T., 12 quarts 8-lb. gum-substitute water, 3½ lbs. alum, 2 oz. chloride of potash, 5 oz. red prussiate. All shades of light browns are made from this by reducing with gum-substitute water, according to shade wanted.

No. 117. *Yellow.*—4 gallons bark at 8° T., 2 quarts red liquor at 18° T., 2 quarts nitrate of alumina No. 109, 12 oz. tin crystals, 5 lbs. starch.

No. 118. *Green for Block.*—25 lbs. yellow prussiate of potash, 6 gallons hot water; in a separate vessel, 10 gallons 6-lb. gum-Senegal water, 2 gallons water, 1 gallon muriate of tin at 120° T.; mix the prussiate solution with the tin and gum by pouring one into the other, and violently agitating; when quite fine and free from flocculent matter, add 12 gallons berry liquor at 10° T., then add 12 lbs. and 2½ lbs. oxalic acid, dissolved in 5 gallons water, then 3 quarts acetic acid, and 2½ gills extract of indigo.

No. 119. *Brown.*—6 quarts berry liquor at 20° T., 6 quarts Brazil wood liquor at 8° T., 3 lbs. alum, 3 quarts lavender liquor, 6 quarts 6-lb. gum-Senegal water, 24 oz. nitrate of copper at 100° T.

After printing, the pieces are hung for some hours to equalize their temperature, and are then steamed.

There are two methods of steaming now commonly employed:—the column and the chest. The column is a hollow cylinder of copper, from 3 to 5 inches in diameter, and about 44 inches long, perforated over its whole surface with holes of about 1/8 of an inch, placed about 1/2 of an inch asunder. A circular plate, about 9 inches diameter, is soldered to the lower end of the column, destined to prevent the coil of cloth from sliding down off the cylinder. The lower end of the column terminates in a pipe, mounted with a stopcock for regulating the admission of steam from the main steam boiler of the factory. In some cases, the pipe fixed to the lower surface of the disk is made tapering, and fits into a conical socket, in a strong iron or copper box, fixed to a solid pedestal; the steam pipe enters into one side of that box, and is provided, of course, with a stopcock. The condensed water of the column falls down into that chest, and may be let off by a descending tube and a stopcock. In other forms of the column, the conical junction pipe is at its top, and fits there into an inverted socket connected with a steam chest, while the bottom has a very small tubular outlet, so that the steam may be exposed to a certain pressure in the column when it is ensnared with cloth.

The pieces are lapped round this column, but not in immediate contact with it; for the copper cylinder is first enveloped in a few coils of blanket stuff, then with several coils of
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White calico, next with the several pieces of the printed goods, stitched endwise, and hastily, with an outward mantle of white calico. In the course of the lapping and unlapping of such a length of webs, the cylinder is laid in a horizontal frame, in which it is made to revolve. In the act of steaming, however, it is fixed upright, by one of the methods above described. The steaming lasts for 20 or 90 minutes, according to the nature of the dyes; those which contain much solution of tin admit of less steaming. Whenever the steam is shut off, the goods must be immediately uncoiled, to prevent the chance of any aqueous condensation. The unrolled pieces are free from damp, and require only to be exposed for a few minutes in the air to appear perfectly dry. Were water condensed during the process, it would be apt to make the colors run.

The other method of steaming, and the one now most generally employed, is that of the chest. This is a rectangular iron chamber, with penthouse top; its dimensions are about 12 feet in length by 6 feet in width, by 9 feet in height at the highest part. It is provided with closely-folding doors at one end, with a cross bar, which can be fastened with wedges or screws. There is a perforated false bottom, at the same level as the room in which the steam chest stands; underneath the false bottom is a perforated pipe, running round three sides of the chest; this pipe admits the steam, which is further diffused by the holes in the false bottom. On the false bottom is laid a pair of rails parallel with the sides of the chest; these rails are continued outside the chest into the room, the parts next the chest for about 3 feet being hinged so as to be moved on one side when the doors are opened or shut. Upon the rails moves a rectangular frame of wood, which just fits inside the chest, and stands as high as the commencement of the slope of the roof. This frame, when drawn out into the room, is filled with pieces in the following manner:—They are first wound on an open reel, one by one, the selvages of each fold being kept as parallel as possible. The piece is then slid off the end of the reel, pulled flat, and a needle and thread passed through all the selvages of one side, and loops made, through which are passed wooden rods, which rest on the sides of the carriage. The pieces being thus suspended with selvages downwards, the carriage, being filled with the rods, is run into the chest, the doors firmly shut, and steam turned on, the steam escaping by a safety valve. They hang thus for 45 minutes, are taken out, unfolded, and loosely folded for washing off. They are next stitched end to end, and passed through a cistern with water, from that into a cistern containing a very weak solution of bichromate of potash; they are then put into a washing machine, hydro-extracted, starched, and dried.

The colors that are fixed by steaming, may, with one or two exceptions, be described as colored lakes temporarily held in solution by acids, and during the steaming, the cloth gradually withdraws these lakes from solution, the acid being either dissipated or so modified as to be incapable of holding the lakes dissolved. The state of the steam is an important matter. It is not the less alone that produces the effect; for it may easily be demonstrated that heating cloth, when printed and dried, has no effect whatever. The steam, to be effective, must be as saturated with moisture as possible, and for this reason the steaming apparatus should never be near the boiler; it is no disadvantage for the steam to travel a considerable distance before being applied. In some print works the steam is made to pass through water in a vessel placed below the steam chest, so that it arrives in the chest perfectly saturated with water. At the same time, the steam must not be of so low tension as to cause a deposit of moisture on the pieces, which would be very injurious, by causing the colors to run or mix. Steam blue depends for its fixation on the decomposition of ferrocyanic acid by the high temperature and presence of vapor water into white insoluble ferrocyanide of iron and potassium, which, by acquiring oxygen from the air or during the washing-off, becomes Prussian blue. The shade of it is much modified by the oxide of tin in the cloth, and the prussiate of tin that forms part of the color. It appears that tin substitutes iron, forming a compound ferrocyanide of tin and iron, or a ferro-stanno-cyanide of iron, which is of a deep violet-blue color. Greens are mixtures of yellow lakes with the Prussian blue, formed by decomposition. In both these colors there is a large quantity of hydrocyanic acid disengaged during the steaming; steam being decomposed, its hydrogen going to form hydrocyanic acid.

Mousseline de laines are treated somewhat in the same manner, the preparation of the cloth being different, and the colors are made in such a manner as to fix equally on both the wool and the cotton of the fabric. The steaming and washing-off is nearly the same as for calicoes. The following is the method in detail:—

The cloth is first well bleached (See Bleaching) and sulphured. This operation is usually performed by hanging the goods in a stone or brick chamber. Trays of sulphur being lighted, the door is closed tight, and the pieces stay in the sulphurous gas for several hours, and are then removed and washed. An improvement on this method was patented by John Thom, and is here shown:—

Thom's Sulphuring Apparatus.—Fig. 138. a is the roof, made of sheet lead, 4 lbs. to the foot. b is a lead pipe, of one inch diameter, taking off the excess of sulphurous acid to the flue. c and d are rolls of pieces, going in on one side and coming off at the other.
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and rollers of wood, three inches in diameter, with iron centres at the ends. E and E, tiles, as in malt kilns, to let the gas pass up through to the cloth.

Fig. 139 shows the chamber; it is six feet in length by four feet in breadth, and about five feet high. There are two windows, which are placed opposite each other. F is a cast-iron tray for burning the sulphur. It is placed on a flag, inclining towards the chamber at about one inch to a foot. It is furnished with a slide, on which to put the sulphur to be pushed in, and to admit what air may be wanted. The space for air may be from half an inch to an inch wide. It costs £18 to £20.

Preparation.—Pad the pieces, previously well bleached, (see Bleaching,) in a wooden padding machine through stannate of soda at 10° twice over, then pass through a cistern with rollers, containing dilute sulphuric acid at 3° T., wash gently, and partially dry, then pad through sulphomuriate of tin at 4° T. twice.

No. 121. Sulphomuriate of Tin.—3 quarts muriate of tin at 120° T., 1 quart sulphuric acid at 170° T., mixed together gradually, and 4 quarts muriatic acid added; reduce to 4° T.

Run from this without washing into a large cistern with rollers, containing dilute chloride of lime at 3° T., then wash, put in the hydro-extractor, and dry. When wanted for print-
ing, pad through gum-Senegal water at 8 oz. to the gallon, and dry. After printing, they are hung on long calicoces to equalize the temperature, then hung in the steam chest in the same manner as calicoces, and steamed 45 minutes. After steaming, they are unrolled and loosely folded for washing-off, which is done by wincing over a reel in a pit of water gently for \( \frac{1}{4} \) of an hour, then transferred to a washing machine or large automatic wince reel, and washed till no more colored liquor comes away, then hydro-extracted, and dried over the steam cylinders. After drying, it is found advantageous to hang the pieces in a cool room, with covered slutter sides, for a day or two, so that they may imbibe a little moisture, and the colors appear richer. The wool in mouseline de laines is apt to be partially decomposed during steaming, and sulphuretted hydrogen liberated, which decomposes the metallic salts, such as nitrate of copper, used in some colors, and produces a very disagreeable effect, termed silvering. To avoid this, it is now customary to wind on the reel for steaming, at the same time as the printed piece, a gray or unbleached piece, which has been padded in a weak solution of acetate of lead, and dried. By this means the printed piece is steamed in contact with the prepared piece, and any sulphuretted hydrogen that may be disengaged is immediately absorbed by the acetate of lead.

The following are the colors used in mouseline de laine printing:

No. 122. Dark Red.—4 gallons cochineal liquor at 10° T., 7 lbs. starch; boil, and when cooled to 180° T., add 13 lbs. oxalic acid, and when this is dissolved, 14 lbs. muriate-of-tin crystals.

No. 123. Chocolate.—6 gallons Sapan liquor at 12° T., 3 gallons logwood liquor at 12° T., 1 gallon bark liquor at 12° T., 16 lbs. starch; boil, and add 5 lbs. alum, 13 oz. chloride of potash, 44 lbs. red prussiate of potash.

No. 124. Yellow.—4 gallons berry liquor at 10° T., 5 lbs. starch, 1 lb. pale British gum; boil, and add 13 lbs. muriate-of-tin crystals.

No. 125. Dark or Royal Blue.—6 gallons water, 4 lbs. starch, 2 lbs. sal ammoniac; boil well, and add 6 gallons tin pulp No. 103; mix well into the paste, and add 16 lbs. pounded yellow prussiate of potash, 8 lbs. red prussiate, 24 lbs. tartaric acid, and 14 lbs. oxalic acid previously dissolved in 4 pints hot water.

No. 126. Pale Blues are made from the dark blue No. 125, by reducing with gum-substituting water, say 1 of dark blue and 7 of gum water for pale blue, for two blues, and 1 of dark blue and 14 of gum water for blotch or ground blue.

No. 127. Green.—4 gallons berry or bark liquor at 12° T., 3 lbs. alum, 6 lbs. starch; boil, and add 6 lbs. powdered yellow prussiate of potash, 1 lb. muriate of tin crystals, 1 lb. oxalic acid, and 25 pints extract of indigo.

No. 128. Pale Green.—6 quarts berry liquor at 6° T., 14 lbs. yellow prussiate of potash, 9½ oz. alum, ½ pint acetic acid, 16 quarts 4-lb. gum-Senegal water, 8 oz. weight muriate of tin liquor at 12° T., ½ pint extract of indigo.

No. 129. Dark Brown.—24 quarts Sapan liquor at 8° T., 1 pint logwood liquor at 12° T., 5 quarts bark liquor at 10° T., 12 oz. alum, 1 oz. chloride of potash, 6 lbs. gum-substituting; boil, and add 4 oz. red prussiate of potash, 2 oz. oxalic acid.

No 130. Pale Brows are made from the dark brown No. 129, by reducing with gum water, say 1 to 3 or 1 to 5.

No. 131. Pale Red.—1 lb. fine ground cochineal, 1 lb. liquor ammonia, specific gravity 0.83; put in a jar with tight-fitting cover, which may be luted down; keep in a warm place for 48 hours, then mix with 2 gallons boiling water, and simmer in a mug down to 1 gallon, then strain off, wash the cochineal with a little water, and strain again; to the liquor made up to 1 gallon add 4 oz. alum, 4 oz. muriate of tin crystals, 4 oz. oxalic acid, and 1 gallon 6-lb. gum-Senegal water.

No. 132. Scarlet.—3 gallons standard No. 156, 1 quart berry liquor at 10° T., 45 lbs. starch; boil, and add 4 oz. oxalic acid, 4 oz. binoxalate of potash, 8 oz. pick salts, (double muriate of tin and ammonia,) and 8 oz. muriate-of-tin crystals.

No. 133. Medium Blue.—6 gallons standard blue No. 156, 1½ quarts oxynilate of tin at 120° T., added gradually, and beaten fine, then \( \frac{2}{3} \) quarts extract of indigo.

No. 136. Standard Blu.—10 lbs. yellow prussiate of potash, 5 lbs. alum, 2 lbs. oxalic acid, 4 gallons water, 4 gallons 6-lb. gum water.

No. 137. Medium Green.—8 quarts berry liquor at 8° T., 3 lbs. yellow prussiate of potash, 1½ lbs. alum, 7 quarts 6-lb. gum water, 1 quart water, 1 quart acetic acid, 14 oz. weight muriate of tin liquor, 1 pint extract of indigo.

No. 138. Lilac.—8 quarts lavender liquor No. 111, 6 oz. oxalic acid, 2 oz. measure extract of indigo.

No. 139. Lavender Liquor.—2 gallons red liquor, 10 lbs. ground logwood; steep 12 hours, and strain off.
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No. 140. Dowel.—6 quarts blue for doves No. 141, 4 quarts lavender liquor No. 111, 8 quarts 6-lb. gum-Senegal water.

No. 141. Blue for Doves.—5 quarts water, 2 lbs. yellow prussiate of potash, 2 lbs. alum, 5 quarts 6-lb. gum water, 1 pint extract of indigo.

No. 142. Orange.—3 gallons berry liquor at 10° T., 9 lbs. gum-Senegal, 3 lbs. red mordant No. 110, 12 oz. muriate-of-tin crystals; boil 15 minutes.

No. 143. Drab Standard.—6 quarts purple liquor No. 141, 1 quart bark liquor at 10° T., ⅜ pint red liquor at 20° T., ⅜ pint extract of indigo.

Drabs are made from this by reducing with gum water about 1 to 3.

No. 144. Purple Liquor.—1 gallon lavender liquor No. 111, 3 oz. oxalic acid.

No. 145. Silver-drab Standard.—3 quarts gall liquor at 12° T., 2 quarts standard blue

No. 136, 1 quart lavender liquor No. 111.

Colors reduced with gum water from this, 1 to 2 or 3.

No. 146. Red Mordant.—1 gallon water, 6 lbs. alum, 3 lbs. white acetate of lead; stir till dissolved, let settle, and use the clear.

No. 147. Buff Standard.—1 quart cochineal liquor at 8° T., ⅘ quarts berry liquor at 10° T., 1 quart red mordant No. 146, 20 oz. oxalic acid.

Colors reduced from this with gum water.

No. 148. Olive.—1 quart lavender liquor No. 111, 2 quarts berry liquor at 10° T., 2 quarts 8-lb. gum-Senegal water.

In mousseline-de-laine printing success depends more on the bleaching and preparing of the cloth than in any other style. To Mr. John Mercer is due the merit of having effected an improvement in the preparation of woolen fabrics, the importance of which can hardly be overrated. Before his discovery of the power of prepared wool to absorb chlorine, mousseline de laines could only be effectively printed by block, which allows a large body of color to be laid on, and the fibre supersaturated with it. Machine colors were meagre and dull. But mousseline de laines prepared with tin, and then subjected to the action of chlorine gas, (as in the process given above, where the acid salt of tin remaining in the cloth, disengages chlorine from the chloride of lime,) have their power of absorbing and retaining color considerably enhanced. The exact part the chlorine plays is not well known, probably a compound similar to the chloro-protein of Mr. Molder is formed. The effect produced is not one, as might be supposed, of oxidation; but apparently a merely heightened power of the wool to assimilate coloring matter. Wool subjected to chlorine without tin is much improved in its capacity for color, but nothing like the same when prepared with tin also. The whole of the chlorine may be removed from the cloth by passing through an alkalii, which renders it necessary to give the stannate-of-soda padding previously to the chlorinating. It may fairly be assumed that the development of mousseline-de-laine printing by cylinder to the present perfection is due in a great measure to this chlorinating process. It ought also to be stated that, with rare liberality, Mr. Mercer gave the discovery to the trade, reserving for himself no right whatever.

Niinth Style: Spirit Colors.

Topical colors of great brilliancy, but possessed of very little solidity, are made somewhat like steam colors, but with much larger proportions of "spirits," by which term is meant the metallic salts and acids, which, combining with the dyestuff depositions, give the peculiar tone and vivacity to these colors. These colors, from the large admixture of these salts, are necessarily very acid, and cannot be steamed without the destruction of the cloth. They are merely gently dried after printing, and hang in the ageing room for several hours, then rinsed in water, washed, and dried.

The following are examples of spirit colors:

No. 149. Black.—1 gallon logwood liquor at 8° T., 1 gallon water, 10 oz. copperas, 3 lbs. starch; boil, and add ⅔ pint precipitate of iron at 80° T.

No. 150. Pink.—1 gallon Sapan liquor at 8° T., 1 gallon water, 2 lbs. common salt, 1½ lbs. starch; boil, cool, and add 1 pint oxymuriate of tin at 120° T., 3 oz. measure nitrate of copper at 80° T.

No. 151. Blue.—1 gallon water, 1 lb. yellow prussiate of potash, 6 oz. alum, 1½ lbs. starch; boil, and add ⅔ pint nitrate of iron at 80° T., 14 gills oxymuriate of tin at 120° T.

No. 152. Brown.—1 gallon berry liquor at 8° T., 2 lbs. light British gum; boil, and add 1 lb. muriate-of-tin crystals, 2 quarts spirit pink No. 150, 2 quarts spirit purple No. 153.

No. 153. Purple.—1 gallon logwood liquor at 8° T., 1 gallon water, 10 oz. copperas, 2 lbs. starch; boil, and add 1 pint protomuriate of iron at 80° T., 1 pint oxymuriate of tin at 120° T.

No. 154. Orange.—11 gallons berry liquor at 8° T., 12 lbs. light British gum; boil, and add 6 lbs. muriate-of-tin crystals, 4 gallons spirit pink No. 150.

No. 155. Chocolate.—⅔ gallon spirit pink No. 150, 1 gallon spirit blue No. 151.

No. 156. Red.—3 gallons Sapan liquor at 4° T., 1 lb. sal ammoniac, 1 lb. verdigris, 4½ lbs. starch; boil, cool, and add 5 lbs. pink salts, 1 lb. oxalic acid.
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No. 157. Yellow.—1 gallon berry liquor at 10° T., 1 lb. alum, 1 lb. starch; boil, and add 1 pint muriate-of-tin liquor at 120° T.

No. 158. Green.—1 gallon spirit blue No. 151, 1 gallon spirit yellow No. 157.

No. 159. Spirit Pink for Blocking Madder Work.—4½ gallons Brazil wood liquor at 10° T., 9 lbs. pink salts, 8 lbs. sal ammoniac, 2 lbs. sulphate of copper, 5½ oz. oxalic acid, dissolved in 1 pint water; 4½ gallons of 6-lb. gum-Senegal water, 1½ quarts oxymuriate of tin at 120° T.

Tenth Style: Bronzes.

The cloth is padded in solution of sulphate of manganese, the strength of which determines the shade of brown produced; for a medium shade of brown, suitable for discharge colors, the liquor may be 80° T.

After padding and drying, pad the pieces through caustic soda at 24° T., and again through caustic soda at 12° T., wince well in water, and then in solution of chloride of lime at 2° T., till perfectly brown; wash well in water, and dry.

The colors for printing on this dyed ground are so made as to discharge the brown and substitute their own color in place of it.

No. 160. Blue Discharge.—(a) 6 gallons water, 3½ lbs. yellow prussiate of potash, 10 lbs. starch, 6 lbs. light British gum; boil, and add 12 lbs. tartaric acid, 6 lbs. oxalic acid, 13 quarts permuriate of iron; then take (b) 5 quarts of this standard, 3 quarts muriate of tin at 120° T.

No. 161. Discharge Yellow for Chroming.—(a) 1 gallon water, 5 lbs. nitrate of lead, 4 lbs. light British gum; boil, and add 4 lbs. tartaric acid; then take (b) 3 quarts this standard, 1 quart muriate of tin at 120° T.

No. 162. Discharge Green.—2 quarts yellow standard No. 161 (a), 1 quart blue standard No. 160 (a), 1 quart muriate of tin at 120°

No. 163. Discharge Pink.—(a) 2 gallons Brazil-wood liquor at 12° T., 4 oz. sulphate of copper, 4 oz. sal ammoniac, 4 lbs. starch; boil, and add 8 oz. measure oxymuriate of tin at 120° T.; then take (b) 2 quarts of this standard, 1 quart muriate of tin at 120°

No. 164. White Discharge.—2 gallons water, 8 lbs. light British gum; boil, and add 8 lbs. tartaric acid, and 1 gallon muriate of tin at 120° T.

Black.—Spirit black No. 142.

After printing, hang for a few hours, and wince in a pit with water freely flowing into it; then wince in chalky water, again in water, then wince in bicromate of potash at 4° T., to raise the green and yellow; wash and dry.

The discharging agent in these colors is the protomuriate of tin, which, by its superior attraction for oxygen, robs the peroxide of manganese of a portion. The protoxide of manganese formed by this change being then soluble in the acid, and subsequently washed away, the pigment Prussian blue and chromate of lead, also the Brazil lake, being left fixed in the discharged place.

Eleventh Style: Pigment Printing.

In this style, the ordinary pigments, such as used in oil-painting, are mechanically attached to the cloth by a species of cementing. The first fixing vehicle used was a solution of esoutruche in naphtha, which was mixed with the pigment so as to make colors of sufficient viscosity to print. The naphtha was then driven off by steaming, and the pigment was then cemented to the cloth by a film of esoutruche. This method makes very fast colors, not affected by soaping and moderate friction; but, unfortunately, the naphtha volatilizing during the printing process, rendered the use of it too dangerous, and after it was found that explosions of the naphtha vapor frequently took place, calico printers turned their attention to some other fixing vehicle. Animal substances, of which the white of eggs is the type, and which, soluble in water, are coagulated by heat, are now usually employed. Of these three may be particularized:—albumen of eggs, lactarine, glutin.

The first is made by simply drying gently the white of eggs, and powdering it. The second is made by separating the solid part of buttermilk, purifying it from butter and free acid, and drying it. The third is the residue of starch making from wheat flour by the simple washing process, the gluten being gently dried.

The two latter thickeners require a small quantity of alkali to bring them in solution; they then resemble albumen in their power of coagulating by heat. There are few colors of this style printed, chiefly ultramarine blue and carbon crab.

No. 165. Ultramarine Blue with Lactarine.—13 lbs. lactarine, 3½ pints water; mix well, and add 24 oz. measure liquid ammoniac, specific gravity 888°, 5 oz. measure caustic soda at 32° T.; then having beaten up 3 lbs. ultramarine with 12 pints water, mix with the lactarine solution.

No. 166. Ultramarine Blue with Albumen.—4 lbs. ultramarine, 3½ quarts water; mix well and add slowly 3 lbs. albumen in powder; let it stand a few hours, stirring occasionally; when dissolved, add 1 pint gum-tragacanth water at 12 oz. per gallon.
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No. 167. Ultramarine Blue with Glutten.—6 lbs. ultramarine, 5 quarts water; mix, and add gradually 3/4 lbs. ground glutten; let it stand a few minutes, then add 1 quart caustic soda at 16° T.; mix well, and let it stand a few hours before using.

Other shades of blue are made by altering the quantity of ultramarine.

No. 168. Dye.—5 lbs. lampblack, 5 plts acetic acid at 8° T.; mix well together, and add a solution of 5 lbs. albumen in 5 pints water; then add 3 plts 12-oo. gum-tragacanth water.

After printing these colors, steam half an hour, wince in water, and dry. Colors fixed in this manner are not intended to resist severe treatment.

No. 169. Pencil Blue.—10 gallons of pulp of indigo, containing 40 lbs. indigo, 40 lbs. yellow ocher; 113 gallons of caustic soda at 70° T.; 184 gallons of water, 4 lbs. bell; boil till quite yellow, when spread on glass; let settle, and thicken the clear with 120 lbs. gum-Senegal.

Pieces printed in pencil blue are washed in water immediately after drying and sometimes soaked a little. Mr. Bennet Woodcroft, struck with the waste of indigo attending the printing of either China blue or pencil blue, some few years ago invented and patented a method of printing pencil blue by the cylinder machine. His plan was to attach to an ordinary single-color machine an Indian-rubber apparatus, which enveloped the color-box and piece after printing; this apparatus was filled with cool gas; a glass plate formed part of the long bag through which the piece travelled after printing, so as to enable the printer to see the progress of his work. By this means the deoxidized indigo was fairly applied to the cloth, and oxidation only ensued when the piece left the apparatus. The saving of indigo was said to be considerable, but the plan was not generally adopted.

Safflower Dyeing.—The beautiful but fugitive coloring matter of safflower is applied in the printing for dyeing a self color, generally after the goods have been printed in black and red mordant, or black alone, and dyed madder or Garance. It is commonly used for cotton velvets, the color given to velvet appearing very brilliant, from the nature of the cloth. The process is as follows.—Safflower contains two distinct coloring matters: one yellow, being soluble in water, and the other pink, insoluble in water, the latter only being valuable. The yellow matter is therefore carefully washed away. To effect this, the safflower is put into canvas bags, 4 lbs. in a bag, and these bags put into running water and occasionally trodden upon till the water runs off perfectly colorless from them. 12 of these bags are then emptied into a cask with 90 gallons of water and 10 quarts of pearlash liquor at 31° T., stirred up for two hours; after standing all night, drain off the liquor, add 30 gallons more water and 3 pints of pearlash liquor; stir up well, and after standing for three hours, drain off again; this weak liquor is saved for putting on fresh safflower: about 30 gallons of the safflower solution is put in a tub mounted with a wince over it, and a mixture of vinegar and lime juice is added to it till it is feebly acid to test paper. The carthamic acid, a red coloring matter of safflower, is thus precipitated, and remains as an exceedingly fine powder in suspension in the liquor; 2 pieces of 30 yards of velvet are put in and winced backwards and forwards 5 times, then wound upon the reel, and allowed to stay there half an hour, then wince 5 times more, wind up again, and let stay half an hour; wince again 5 times, and wind up again; run off the liquor and put in 30 gallons of fresh liquor and acid as before; repeat the process, wincing 5 times of 5 ends each, and letting lie wound on the reel half an hour each time; then take out and wince in very dilute acetic acid, hydroextract, and dry. The pieces, when wound on the reel, should be opened out flat, or they might be uneven. Carthamic acid, being of a resonant nature, has the property of attaching itself to cloth, and dyeing in a beautiful pink like the petals of a rose; this dye is very fugitive, strong sunlight even being injurious to it. There has been no way yet discovered of making it permanent.

Murexide.—The purpurate of ammonia, or murexide, was discovered by Liebig and Wöhler in 1833, and in its pure state is one of the most beautiful products of chemistry. It is a crystalline substance of a beautiful metallic green, like the wings of the cautharides fly, and is produced when uric acid is dissolved in dilute nitre acid, the solution evaporated somewhat, and ammonium added; from the beautiful crimson liquid, murexide crystallizes. This substance had, until a short time ago, no practical application. M. Albert Schlumberger discovered that metallic insoluble salts, possessing all the brilliancy of the original substance, could be made; and this fact was soon applied to a practical use by the French chemists, who succeeded in fixing a beautiful murexide crimson upon cotton cloth. The process was patented in this country for French interests in February, 1837, and is now in extensive use. The process is as follows:—

Print in the color.

No. 170. 1 gallon water, 4 lbs. nitrate of lead, 1 lb. murexide, 15 lbs. starch; boil. After printing, hang a few hours, then run through a cistern with rollers above and below, and provided with a cover, through apertures in which the pieces enter and leave. This cistern is kept supplied with ammoniacal gas; on leaving this cistern, they pass into water, and from that into a cistern charged with 2 lbs. bichloride of mercury, 4 lbs. acetate of
soda, 4 lb. acetic acid, 80 galls water; run very slowly through this, wash and dry. In the first operation purpureate of lead is formed on the cloth, and in the second, or changing bath, the lead is wholly or partly removed, and oxide of mercury left in its place, the resulting lake is a color of great brilliancy and purity, so much so that few of the ordinary colors will bear to be looked at along with it. Though perfectly fast as to soap, it appears that strong sunlight is rather injurious to its permanence.

A few outline illustrations of the various madder styles will render them more clear.

1. Black. Print in colors 4, 11, 34, and 18; when dry, cover with a fine pattern in 37, (12 shade;) age 3 nights; fly-dung at 170° F., second dung at 160° F., wash, dye, and clean as 1 a.

2. Black, red, white, and brown figures, covered in purple. Print in colors 4, 11, 34, and 18; when dry, cover with a fine pattern in 37, (12 shade;) age 3 nights; fly-dung at 170° F., second dung at 160° F., wash, dye, and clean as 1 a.

3. For chintz work treat as 1 a, then in the parts of the pattern meant for groundwork, block the colors 118 yellow, 119 green, and 129. If the pattern is such as to admit of it, all these colors may be printed at once from one block, using the tobying sieve, p. 226: the colors, however, for this method must be thickened with gum; steam, &c., as described for steam colors.

4. Black, 2 reds, purple and brown on white ground. Print by machine in colors 4, 5, 6, 9, 27, (No. 12 shade,) and 18; age 3 nights; fly-dung at 160° F., second dung at 150° F., wash and dye with French or Turkey madder, bringing to boil in 15 hours, and boiling 4 hour; wash and soap twice at 180° F., wash; chloride of lime bath, (see No. 1 plate purples,) wash and dry.

5. Black, red, white, and brown figures, covered in purple. Print in colors 4, 11, 34, and 18; when dry, cover with a fine pattern in 37, (12 shade;) age 3 nights; fly-dung at 170° F., second dung at 160° F., wash, dye, and clean as 1 a.

6. Print in colors 6, 7, (No. 3 shade,) 34; dry and cover in 7, (6 shade,) and blotch (or pad with a roller engraved with a pin, which has the effect of giving a uniform shade) in 7, (10 shade:) age three nights, and treat as described under the head Swiss Pink.

7. Some printers prefer to mould for Swiss pinks with alkaline mordants, considering the composition of the colors to be a guarantee against their coagulating iron; in such case, they print in colors 31, 32, and 35, covering in pole shades of 32 after dyeing; fly-dung with 3 cwt. cow-dung, 12 lbs. sal-ammoniac, 1,000 gallons water at 110° F.; second dung with 2 cwt. cow-dung at 110° 15 minutes; wash and dye as for 1 e. In this method of mordanting, the aluminate of soda that has escaped decomposition by the carbinic acid of the air, is decomposed by the murrate of ammonia, and alumina precipitated on the cloth. If the pieces are to be used for curtains or the like, instead of being printed after being put into the dye bath, the pieces are immersed in the dye bath, then taken out, allowed to stand a short time, after which, they are put into the dye bath, and allowed to stand a short time longer. The pieces are then immersed in cold water, and the dyeing process is repeated until the necessary depth of color is obtained.

8. For furniture hangings, which are generally printed in large groups of flowers, a very pretty pea-green ground is often block-in as groundwork, which is made and fixed as follows:—

171. Pea Green.—(a) Standard: 6 lbs. sulphate of copper, 1 gallon water, 4 lbs. brown acetate of lead; dissolve, let settle, and use the clear.—(b) Color: 2 measures of standard, 1 measure of 7 lb. gum-Senegal solution.

After printing, age 2 nights, and pass through a eistern with rollers, set with caustic potash liquor at 15° T., which has 8 oz. per gallon of arsenious acid dissolved in it. The liquor should be heated to 110° F.; out of this wash and dry.

Instead of block-in steam blue and green, fast blue and green are introduced where the colors required are to be particularly permanent; colors 62 or 63 or both are block-in and raised as follows:—5 stone eisters, each mounted with a hand reel, and containing about 200 gallons each, are set with carbonate-of-soda liquor, No. 1 at 7 T., No. 2 at 6 T., No. 3 at 5 T., No. 4 at 4 T., and No. 5 at 3° T.; wine 10 times backwards and forwards in each pit, beginning with No. 1, and ending with No. 5; wine in water and wash. The change that takes place here is similar to that in raising China blues. The indigo is maintained in a deoxidized state by the protioxide of tin formed, until it has fixed itself in the cloth by reoxidation in the air.

Where fast green has been printed, the pieces are winced in bichromate-of-potash liquor at 4° T. for 10 minutes, then washed and dried. After, in 1 cwt. white and brown on white ground, (see No. 27, (12 shade,) age, dung, and dye, &c., as directed for plate purples, (p. 252:) block over the pattern and portions of the unprinted part the paste No. 39; block with pad roller in No. 55, (6 shade,) dry
and raise as follows:—Wince 14 minutes in caustic soda at 2° T. at 110° F., then wince in water till quite buff, then wince in 400 gallons water with 1 quart chloride of lime at 12° T. 10 minutes; wash and dry.

Silk Printing.

Silk, in its capacity for receiving colors, holds a medium place between cotton and wool. From its being an animal substance, it is difficult to obtain white grounds or objects after dyeing mordanted silk, the silk itself attracting coloring matter somewhat as a mordant.Previously to printing silk, it is usually secured by boiling for 2 hours with 4 lbs. of soap to every pound of silk, then well washed and dried. For handkerchiefs, black, chocolate, and red mordants are printed, aged, and dumped off same as for cottons, and dyed with madder or garancin, soaped, washed, and dried. Purples cannot be obtained on silk by mordanting and dyeing madder, the color produced being a mixture of red and purple. All sorts of colors can be produced on silk by steam, the whites remaining brilliant. For steam colors, silk is mordanted with tin, by steeping 4 hours in a solution of sulphomuriate of tin at 90° T. made by dissolving 1 lb. of muriate-of-tin crystals in water, and adding 1 lb. of sulphuric acid at 170° T. and reducing to 2° T. After steeping, the silk is washed with water, and dried. The following are specimens of steam colors for silk:—

Black.—2 gallons logwood liquor at 8° T., 1 quart iron liquor at 10° T., 1 lb. flour, 1 lb. light British gum; boil, and add 5 oz. yellow prussiate of potash; cool, and add 2 oz. sulphate of copper, 1 pint muriate of iron at 90° T. ¼ pint pernitrate of iron at 80° T.

Chocolate.—2 gallons of sapan liquor at 12° T., 5 quarts logwood liquor at 12° T., 1 quart bark liquor at 10° T., 2 lbs. alum, 1½ lbs. sal ammoniac, 14 lbs. gum-Senegal.

Red.—3 gallons of cochineal liquor at 4° T., 1½ pints bark liquor at 12° T., 3 lbs. starch; boil, then cool, and add 1 lb. oxalic acid, 1 lb. muriate-of-tin crystals.

Yellow.—3 gallons of bark liquor at 10° T., 8 oz. alum, 3 oz. muriate-of-tin crystals, 3 oz. oxalic acid, 9 lbs. gum-Senegal.

Green.—1 gallon yellow, ½ pint extract of indigo, 2½ oz. measure of muriate of tin at 120° T.

Blue.—1 gallon water, 1 lb. yellow prussiate of potash, ½ lb. oxalic acid, ½ lb. tartaric acid, 2 oz. sulphuric acid at 170° T., 1 gallon 6 lbs. gum-Senegal water.

Gallow, &c., printing less, is well secured by boiling for 2 hours with 4 lbs. of soap to every pound of silk, then well washed and dried.

Since that period there are no data as to the number of printers in Great Britain; but Mr. John Graham, in an unpublished "History of the Lancashire Printers," gives a table, which he was at considerable care to compile from perfectly trustworthy sources, showing that in the Lancashire district, which includes also the contiguous counties, there were, in 1846, 128 firms, employing—

549 cylinder machines.

33 perrotines.

7,187 block tables.

The producing power of the Lancashire district having thus been doubled in 6 years. Several printing firms, both in England and Scotland, have since that period much enlarged their powers of production. There are many who manufacture 10,000 pieces of printed cloth per week; and there are four concerns, of great magnitude, whose united production at the present time probably does not fall short of four millions of pieces per annum, or nearly ⅓ of the total quantity printed.

The following estimate of the exports of printed goods is from Mr. Potter's Lecture before the Society of Arts, as reporter for printed fabrics exhibited in the Exhibition of 1851:—

"In reference to the exports of printed goods, our information is rather obscure, owing to their being classed with dyed goods of all kinds." "After considerable thought and calculation, I have ventured to estimate them for 1851 at 15,544,000 pieces, or rather
CALICO PRINTING.

more than three-fourths of our entire production. These goods are, however, many of them of the cheap and more staple class of prints, or slight goods suited to warm climates, and for markets where cheapness is the great recommendation. In value, I should be disposed to estimate our export of printed goods at £25,776,000.

"In reference to the entire export of manufactured cotton goods, (exclusive of yarns,) it may be presumed that out of £28,447,103, given as the exports of 1851, about one-fourth may be placed to the account of the print trade. I have endeavored to estimate, from the Table of Exports for 1851, the probable quantity of low-priced prints we export, and should be disposed to class them as follows:—

<table>
<thead>
<tr>
<th>&quot;Coast of Africa and the Cape&quot;</th>
<th>Pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand and South Sea Islands</td>
<td>300,000</td>
</tr>
<tr>
<td>China, Manilla, and Singapore</td>
<td>500,000</td>
</tr>
<tr>
<td>British West Indies</td>
<td>300,000</td>
</tr>
<tr>
<td>Foreign West Indies</td>
<td>300,000</td>
</tr>
<tr>
<td>St. Thomas</td>
<td>200,000</td>
</tr>
<tr>
<td>India</td>
<td>1,570,000</td>
</tr>
<tr>
<td>Mauritus and Batavia</td>
<td>325,000</td>
</tr>
<tr>
<td>Chili and Peru</td>
<td>800,000</td>
</tr>
<tr>
<td>Brazil and East Coast of South America</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Egypt</td>
<td>84,000</td>
</tr>
<tr>
<td>Turkey, Ionian Isles, Greece, and Malta</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>

Total | 6,150,000 |

"I find those countries which take our lowest description of goods, and where the duties are chiefly very light—our colonies, India, and China, receive from us about 6½ millions of pieces, or about 40 per cent. of our exports in printed goods. A great proportion of the finer part of our exports, perhaps three-fourths, are very seriously taxed, either for protection, as in the United States, the Zollverein, and Belgium, or for revenue, as in Brazil and the other South American markets. A part, however, of these better goods find their way into consumption in Canada, Turkey, the Ionian Isles, Egypt, &c., subject to very moderate duties." (Potter.)

Exports of Calicoes printed and dyed in 1857.

<table>
<thead>
<tr>
<th>Yards</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>1,618,080</td>
</tr>
<tr>
<td>Sweden</td>
<td>624,418</td>
</tr>
<tr>
<td>Norway</td>
<td>787,289</td>
</tr>
<tr>
<td>Hanover</td>
<td>1,054,564</td>
</tr>
<tr>
<td>Hanse Towns</td>
<td>26,306,001</td>
</tr>
<tr>
<td>Holland</td>
<td>12,399,706</td>
</tr>
<tr>
<td>Belgium</td>
<td>909,744</td>
</tr>
<tr>
<td>France</td>
<td>5,130,577</td>
</tr>
<tr>
<td>Portugal, Azores, and Madeira</td>
<td>18,956,056</td>
</tr>
<tr>
<td>Spain and Canaries</td>
<td>8,767,747</td>
</tr>
<tr>
<td>Sardinia</td>
<td>11,008,456</td>
</tr>
<tr>
<td>Tunisia</td>
<td>6,602,902</td>
</tr>
<tr>
<td>Papal States</td>
<td>4,814,905</td>
</tr>
<tr>
<td>Two Sicilies</td>
<td>7,438,118</td>
</tr>
<tr>
<td>Austrian Territories</td>
<td>7,191,273</td>
</tr>
<tr>
<td>Greece</td>
<td>3,379,548</td>
</tr>
<tr>
<td>Turkey</td>
<td>70,900,285</td>
</tr>
<tr>
<td>Wallachia and Moldavia</td>
<td>1,130,001</td>
</tr>
<tr>
<td>Syria and Palestine</td>
<td>16,061,817</td>
</tr>
<tr>
<td>Egypt</td>
<td>11,545,985</td>
</tr>
<tr>
<td>West Coast of Africa (Foreign)</td>
<td>18,817,282</td>
</tr>
<tr>
<td>Java</td>
<td>16,811,862</td>
</tr>
<tr>
<td>Philippine Isles</td>
<td>9,548,904</td>
</tr>
<tr>
<td>China</td>
<td>12,830,544</td>
</tr>
<tr>
<td>South Sea Islands</td>
<td>1,552,339</td>
</tr>
<tr>
<td>Cuba</td>
<td>14,144,771</td>
</tr>
<tr>
<td>Porto Rico</td>
<td>3,109,800</td>
</tr>
<tr>
<td>Caracas</td>
<td>785,478</td>
</tr>
<tr>
<td>St. Thomas</td>
<td>20,229,211</td>
</tr>
<tr>
<td>Haiti</td>
<td>5,191,029</td>
</tr>
<tr>
<td>United States</td>
<td>106,828,383</td>
</tr>
<tr>
<td>Mexico</td>
<td>10,205,758</td>
</tr>
</tbody>
</table>
CALICO PRINTING.

Exports of Calicoes printed and dyed in 1837. (Continued.)

Declared real value.

<table>
<thead>
<tr>
<th>Country</th>
<th>Yards,</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central America</td>
<td>3,721,458</td>
<td>86,827</td>
</tr>
<tr>
<td>New Granada</td>
<td>14,618,606</td>
<td>229,316</td>
</tr>
<tr>
<td>Venezuela</td>
<td>6,564,167</td>
<td>107,417</td>
</tr>
<tr>
<td>Brazil</td>
<td>84,304,766</td>
<td>1,545,479</td>
</tr>
<tr>
<td>Uruguay</td>
<td>8,719,894</td>
<td>149,294</td>
</tr>
<tr>
<td>Buenos Ayres</td>
<td>17,870,563</td>
<td>319,670</td>
</tr>
<tr>
<td>Chili</td>
<td>21,556,565</td>
<td>305,982</td>
</tr>
<tr>
<td>Peru</td>
<td>23,246,258</td>
<td>368,362</td>
</tr>
<tr>
<td>Gibraltar</td>
<td>7,860,972</td>
<td>125,567</td>
</tr>
<tr>
<td>Malta</td>
<td>3,208,445</td>
<td>46,912</td>
</tr>
<tr>
<td>Ionian Islands</td>
<td>3,790,955</td>
<td>55,868</td>
</tr>
<tr>
<td>West Coast of Africa (British)</td>
<td>7,356,177</td>
<td>157,879</td>
</tr>
<tr>
<td>South Africa (British)</td>
<td>9,875,347</td>
<td>166,889</td>
</tr>
<tr>
<td>Mauritius</td>
<td>7,556,558</td>
<td>111,725</td>
</tr>
<tr>
<td>British East Indies</td>
<td>89,717,066</td>
<td>1,518,807</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>2,621,464</td>
<td>41,291</td>
</tr>
<tr>
<td>Australia</td>
<td>15,769,817</td>
<td>310,660</td>
</tr>
<tr>
<td>British North America</td>
<td>19,479,981</td>
<td>331,106</td>
</tr>
<tr>
<td>British West Indies and B. Guiana</td>
<td>21,277,009</td>
<td>299,710</td>
</tr>
<tr>
<td>Honduras</td>
<td>4,090,657</td>
<td>45,375</td>
</tr>
<tr>
<td>Other Countries</td>
<td>1,964,333</td>
<td>36,007</td>
</tr>
</tbody>
</table>

808,308,002 £213,921,428

"The home-consumption," says Mr. Potter, "I estimate at 4,500,000; the exact returns for 1830, gave it as 2,281,512 pieces. The repeal of the duty, and the decrease in the cost of production, giving the consumer goods in much better taste and value at one-half the price, have greatly tended to this increase. "The immense increase of production in lower goods has not decreased the consumption in the higher in this country, though it may have caused it to make less apparent progress than when the larger part of the supply was of fine goods. We find specimens of good taste on the lowest material, printed at the lowest possible price for export, showing a taste superior to that in use for our best work twenty years ago, employing greater talent in design, greater skill in engraving,—the cost of production cheap, because repaid by the quantity produced. This diffusion of art and of a better taste cannot be otherwise than beneficial, even to the higher class of productions, as preparing a taste and demand for them in countries where high price would never have given prints any admission. The improvement of the lower cannot militate against that of the higher, either in the moral, intellectual, or artistic world. The productions of the highest class of French goods of to-day, whether furniture or dresses, are superior in taste and execution to those of any former period. The productions of the first-class printers of Great Britain maintain an equal advance, and are superior in taste and execution, in every respect, to those of former years. Great competition and rapidity of production are not immediately beneficial to high finish and execution in art; but this tendency to quickness of production, rather than perfection, rectifies itself; and machinery, which perhaps at first does not give the polish that excessive labor formerly supplied, ultimately exceeds it by its cheaper and more regular application. It is remarkable how taste or novelty in that class of demand, which would strike the casual observer as the one fitted for its greatest development, is limited in quantity. The limit or commencing point in which taste or novelty enters freely into the composition of a print, is for the supply of the working and middle classes of society. They require it quiet, modest, and useful; and any deviation, for the sake of novelty, which calls in the aid of the brighter and less permanent color, quickly checks itself. The sober careful classes of society cling to an inoffensive taste, which will not look obsolete and extravagant after the lapse of such a time as would render a garment comparatively tasteless and unfashionable in a higher class. This trade is, to the printer, most extensive and valuable, and has its necessary and practical bearing on his taste; and hence it is in this branch of the business the English printer is most decidedly superior to his French competitors."

It would appear that occasionally attempts were made, during the early days of printing, to produce work possessing a high degree of artistic excellence; and as the specimens that have been preserved to our time are very rare, it is fair to conclude that these experiments were not successful in a pecuniary point of view. In the museum of the Wed Park, at Saltford, there is a curious and interesting piece of printed linen, bearing the date 1761, (at this period cloth of all cotton was prohibited,) and which must have been printed from copper plates of very unusual size. Apparently, the pattern has been produced by two plates, each about 4 feet 6 inches by 3 feet. The design is printed in madder red, and is thus described.
CALOMEL.

by Mr. Plant, the curator of the museum: "The printed piece of linen measures, in the full length of the design, 6 feet 10 inches, by 3 feet 2 inches in breadth. The composition in the design is very bold and free—in my opinion indicating very strongly the feelings of an artist who had been educated in the Flemish school. The grouping of the trees, figures, cattle, and fowls is probably a direct copy from an engraving or sketch by Berghem, whose paintings and engravings of such subjects are well known for their truth to nature. His works bear date 1635 to 1680. Perhaps, to fill up the design, and form a picturesque composition, the artist has borrowed from the French painters the classic ruins which form the sides of the design; it has had the effect of producing an anachronism. The upper group represents a peasant seated upon the wall of a well, blowing a flute; near him stands a woman with a distaff; a group of sheep, cow, and a dog, in the foreground. The background shows a landscape, and on each side this group are ruins, columns, and trees, reflected in the stream below. On a broken bank, midway between the two groups, are two dogs chasing a stag. The lower group, although there is no defined line of separation between the groups, represents a peacock, fowls, and chickens, upon a bank and ruins; landscape and river scenery beyond. Over, a hawk carrying a chicken, the sides occupied with a ruined portico, tomb, and pedestal and vase, trees, and broken ground; and below are ducks swimming, and water-plants on the bank. At the bottom of the piece are those parts of the pattern which would print or fit on the top part of the design. On the stone-work of the well, in the upper group, is printed, 'R. JONES, 1761;' on the broken stonework, in the centre of the lower group, is printed, 'R. I. and Co., OLD FORD, 1761.'" Old Ford is situated at Bow, where the East London Water Works now are, and where there was a print work at the time specified. This design was no doubt printed for furniture hangings or tapestry, for which it is exceedingly well adapted, the work being altogether a remarkable production for the period.

CALOMEL. Professor Wöhler proposes to prepare calomel in the humid way by decomposing a solution of corrosive sublimate by sulphuric acid. The commercial salt is dissolved in water at 123° to saturation. Sulphurous acid gas, evolved by heating coarse charcoal powder with concentrated sulphuric acid, is passed into the hot solution: the separation of the calomel commences immediately. When the solution is saturated with the gas, it is digested for some time, then left to get cold, and filtered from the calomel, which is afterwards washed. The filtrate usually contains some unchangeable corrosive sublimate, which may be converted into calomel, either by heating to boiling, or by a fresh introduction of sulphuric acid and heating. Calomel obtained in this manner is a crystalline powder of dazzling whiteness, glittering in the sunlight.

The presence of corrosive sublimate in calomel is easily detected by digesting alcohol upon it, and testing the decanted alcohol with a drop of caustic potash, when the characteristic brick-colored precipitate will fall, if any of that salt be present. To detect sublimate of mercury in calomel, digest dilute nitric acid on it, and test the acid with potash, when a precipitate will fall in case of that contamination. As it is a medicine so extensively administered to children at a very tender age, its purity ought to be scrupulously watched. 117-75 parts of calomel contain 100 of quicksilver. H. M. N.

CAMBOGIA. See CAMBOGAE.

CAMEO. (Came, Fr.; Camaico, Ll.) Correctly a precious stone engraved in relief, as opposed to an intaglio, which is cut into the stone. The earliest cameos appear to have been cut upon the onyx, and, subsequently, on the agate. The true cameo is formed upon a stone having two or more layers, differing in color; and the art of the cameo engraver consists in so cutting as to appropriate those differently colored layers to distinct parts or elevations of the work.

Many of the varieties of calecedony present in section transparent and opaque layers; and beautiful works have been cut upon such specimens of this material. The calecedony and agate are, however, not unfrequently colored artificially. The layers vary very much in their structure, some being absorbent and others not so. Such stones are taken, and if it is desired to have black and white layers, they are boiled in a solution of sugar or honey, and then in sulphuric acid. The sugar or honey is, in the first place, absorbed by the more porous layers, and then decomposed by the acid. Red or brownish-red layers are produced, by occasioning the stone to absorb a solution of sulphate of iron, and then, by exposure to heat, effecting the oxidation of the metal. This being done, layers very strongly contrasted in color are the result, and very fine cameos have been cut upon stones so prepared. In Italy and in France, the art of producing the cameo dur has been, to some extent, revived; but the immense labor which such hard materials require, renders them so expensive, that these cameos have not come into general use.

Porcelain and glass have been employed as substitutes for the natural stones, but the results were so inferior, that these materials have of late been entirely neglected for this purpose.

The shells of several molluscan animals are now commonly used. Many of these shells afford the necessary variety of color, are soft enough to be worked with facility, yet hard enough to wear for a considerable time without injury.
CAMPHENE.

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The natural history of the mollusca producing the shells, and the best account of the manufacture of cameos, was given by J. E. Gray, of the British Museum, in a paper read before the Society of Arts in 1847, to which, and to his paper in the Philosophical Transactions, we are indebted for much of the information contained in this article.

It was the custom in Holland to use the pearly nautilus as a cameo shell, and several kinds of turbines or wreath shells, which have an opaque white external coat over an internal pearl one. These are now rarely employed. The shells now used are those of the flesh-eating univalve, (Gasteropoda pterobranchiata zoophaga,) which are peculiar for being all formed of three layers of calcareous matter, each layer being composed of three perpendicular laminae placed side by side; the laminae forming the central layer, large placed at right angles with one of the inner and outer ones; the inner and outer being placed longitudinally with regard to the axis of the line of the shells, while the inner laminae are placed across the axis, and concentrically with the edge of the mouth of the cone of the shell. (Gray, Phil. Trans.)

This structure furnishes the cameo cutter with the means of giving a particular surface to his work, a good workman always putting his work on the shell in such a manner, that the direction of the lamina of the central coat is longitudinal to the axis of his figure. The central layer forms the body of the bas-relief, the inner lamina being the ground, and the outer one, the third or superficial color, which is sometimes used to give a varied appearance to the surface of the figure. The cameo cutter, therefore, selects for his purpose those shells which have three layers of different colors, as these afford him the means of relieving his work; and secondly, those which have the three colors strongly adherent together, for, if they separated, his labor would be lost.

The following are the kinds of shells now employed: 1. The bull's mouth, (Cassis rufum,) which has a red inner coat, or what is called a sardonyx ground. 2. The black helmet, (Cassis Madagascaerensis,) which has a blackish inner coat, or what is called an onyx ground. 3. The horned helmet, (Cassis cornutum,) with a yellow ground. 4. The queen's conch, (Strombus gigas,) with a pink ground.

The bull's mouth and the black helmet are the best shells. The horned helmet is apt to separate from the ground, or double, and the last, the queen's conch, has but seldom the two colors marked with sufficient distinctness, and the finish of the ground color flies on exposure to light.

The red color of the bull's mouth extends only a slight distance into the mouth of the shell, becoming paler as it proceeds backwards. The dark color extends further in the black and yellow varieties. Hence, the bull's mouth only affords a single cameo large enough to make brooches of, and several small pieces for shirt-studs. The black helmet yields on an average about five brooches, and several pieces for studs, while the queen's conch affords only one good piece.

Forty years since, very few cameos were made from any shells but the black helmet, and the number of shells then used amounted to about 300 annually, nearly all of which were sent from England, being all that were then imported. The black helmet is imported into England from Jamaica, Nassau, and New Providence. They are not found in Madagascar, though naturalists have for a long period called them Madagascacer helmets. (Gray.)

Of the bull's mouth, half are received direct from the Island of Bourbon, to which place they are brought from Madagascar, and the other half are obtained from the Island of Ceylon, being received by the way of Calcutta; hence they are often called “Calcutta shells.”

So rapidly has the trade in those shells increased, that Mr. Gray informs us, that in Paris 100,500 shells are used for cameos annually. These are divided as follows:

<table>
<thead>
<tr>
<th>Price.</th>
<th>Value.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull's mouth</td>
<td>£6,400</td>
</tr>
<tr>
<td>Black helmet</td>
<td>1,920</td>
</tr>
<tr>
<td>Horned helmet</td>
<td>60</td>
</tr>
<tr>
<td>Queen's conch</td>
<td>725</td>
</tr>
</tbody>
</table>

Sterling £29,105

The manufacture of shell cameos was for some time confined to Italy; about twenty years since, an Italian commenced making them in Paris, and now the trade is confined principally to the French capital, where not less than 300 persons are engaged in the manufacture.

Nearly all the cameos made in France are sent to England. In Birmingham, many of them are mounted as brooches, and exported to America and the British colonies.

In 1856 we imported, of shell cameos not set, to the value of £5,683.

CAMPHENE. Rectified oil of turpentine is sold in the shops under this name for burning in lamps. Crude oil of turpentine is redistilled with potash, and then with water, and lastly, to secure its perfect purity, with chloride of calcium. The oil thus prepared
forms a limpid, colorless liquid; its specific gravity is about 0.790, but it is subject to some slight variations; C\(^6\)H\(^2\) appears fairly to represent this and several other similar oils. It is very inflammable, burning with a bright white flame, and without a proper supply of air it evolves much dense smoke, hence peculiar lamps (Camphene Lamps) are required. Where it has, from exposure to air, absorbed oxygen, and become resintified, it is unfit for purposes of illumination. Such camphene very rapidly elogs the wick with a dense carbon, and is liable to the thick black smoke, which is so objectionable in the camphene lamps if they are not properly attended to.

To purify old camphene, it must be redistilled from carbonate of potash, or some similarly active substance to deprive it of its resin. See Lamps.

Camphor. One of the oils obtained from coal tar. Manfield gives this name to the oils cumole and cynole, which boil at 284°F and 328°F Fahrenheit, when collected together. The specific gravity of crude camphole ranges from 0.88 to 0.98, and the less volatile portions frequently contain naphthaline, which raises their specific gravity. This substance, either alone or mixed with pyroxylic spirit, is applicable for burning in lamps or for dissolving resins, as a substitute for oil of turpentine.

Camphor. There are two kinds of camphor imported:

Japan Camphor, called Dutch Camphor, because it is always brought by the Dutch to England. It comes by the way of Batavia, and is imported in tubs (hence it is called tub camphor) covered with matting, and each surrounded by a second tub, secured on the outside by hoops of twisted cane.

China Camphor, or Formosa Camphor, is imported from Singapore and Bombay in chests lined with lead-foil containing about 1½ cwt.

It has been suggested to introduce the camphor trees into other countries. South Georgia and Florida are named as suitable localities.

The Larus camphora is commonly found in all the nurseries around Paris, and sold at 5 francs for a plant 50 inches high. At full growth the tree attains an altitude of from 40 to 50 feet.

The wood of the camphor tree is in favor for carpenter’s work; it is light, easily worked, durable, and not liable to be attacked by insects.

It is said that in Sumatra numbers of trees are cut down before one is found to repay. Not a tenth part of the trees attacked yield either camphor or camphor oil.

The camphor is distinguished by the names of head, belly, and foot, when in bulk. The head camphor is in large white flakes; the belly camphor, small brown flakes, transparent, like resin coarsely powdered; the foot, like dark-colored resin. A native “catty” may be divided into:

1. Capello, or large head
2. Capello cachell, or small head
3. Baldun, or belly
4. Cakoo, or foot

= 1 Catty

= 2.2
= 3.5
= 4.2
= 6.1

= 16

The inquiries of Boyle and Roxburgh agree with the records of Sir G. Staunton, Dr. Abel, and Mr. G. Grove, of the estimation placed upon the camphor of Borneo by the Chinese, who actually give a greater price for the coarser article than they afterwards sell it for, when in a purified state for commerce. Hence it is inferred that the Borneo camphor, being so strong, communicates its odor and virtues to other matters, and thus an adulterated drug is sold by the Chinese; or it may be mixed with the camphor obtained by cutting and macerating the wood of the Larus camphora, that grows in China. Sir G. Staunton, however, declares the Chinese sell the camphor at a lower price than they give for it at Borneo.

Our importations in 1856 were:

Camphor, unrefined
4,505 cwt.

Camphor, refined      626 "

Camphor, Artificial. When hydrochloric acid (muriatic) is passed into oil of turpentine, surrounded by ice, two compounds are obtained, one solid, and the other liquid. The first, solid artificial camphor, C\(^6\)H\(^2\)HCl, is white, transparent, lighter than water, and has a camphoraceous taste. The fluid is termed liquid artificial camphor, or terebine.

Camphor, Oil of Laurel. When the branches of Camphora officinarum are distilled with water, a mixture of camphor and a liquid essential oil is obtained. This is the oil of camphor; it has a density of 0.910, and its composition is C\(^6\)H\(^2\)O. By exposure to oxygen gas, or to the action of nitric acid, it absorbs oxygen, and becomes solid camphor, C\(^6\)H\(^2\)O.

This is an esteemed article in the eastern market; it undergoes no preparation, and though named oil, it is rather a liquid and volatile resin. The natives of Sumatra make
CANDLES.

a transverse incision in the tree to the depth of some inches, the cut sloping downwards, so as to form a cavity of the capacity of a quart; a lighted reed is placed in it for about 10 minutes, and in the space of a night the cavity is filled with this fluid. The natives consider this oil of great use as a domestic remedy for strains, swellings, and inflammations.

Dr. Royle states the trees are of large dimensions, from 2½ to 7 feet in diameter. The same tree that produces the oil, would have produced the camphor if unmolested, the oil being supposed to be the first stage of the camphor's forming, and is consequently found in younger trees.

CAMPHOR STORM GLASSES. Glassess called usually storm glasses, and sold as indicators of atmospheric changes.

"Storm glasses" are made by dissolving:

Camphor - - - - - - - - - - - - 2½ drachms
Nitre - - - - - - - - - - - - - - - - 38 grains
Sal ammoniac - - - - - - - - - - - - 38 grains
Water - - - - - - - - - - - - - - - - 9 fluid drachms
Rectified spirit of wine - - - - - - - - - - - - 11 fluid drachms.

Plumose crystals form in the glass, and are said to condense and collect at the bottom of the bottle on the approach of a storm, and to rise up and diffuse themselves through the liquid on the approach of fine weather; but Dr. Parnon thinks that their weather-predicting qualities are false, and that light is the agent which, together with temperature, influences the condition.

CAM-WOOD. An African dye-wood, shipped principally from Sierra Leone in short logs. Mr. Loddiges, in his botanical cabinet, figures the plant, producing under the name of Baphia nitida; it is a leguminous plant, and has been introduced into, and has flowered in, this country.

CANADIAN BALSAM. A product of the Abies balsamea, or balm of Gilead fir. The finer varieties of this balsam are used for mounting objects for the microscope. See BALSAMS.

CASY WOOD. A wood is imported into this country under the name of Madeira mahogany, which appears to be this canary wood. It is the produce of the Royal Bay, Lauras indica, a native of the Canary Islands. It is rather a light wood, and of a yellow color.

CANDLES. In a lecture delivered at the Society of Arts by Mr. Wilson, and published in their journal, he described the progress of the more recent improvements. In this he says: "Candles, beautiful in appearance, were made by distilling the cocoa-nut acids; but, on putting them out, they gave off a choking vapor, which produced violent coughing." This prevented those candles from being brought into the market. "By distilling cocoa-nut lime soap, we made beautiful candles, resembling those made from paraffine, burning perfectly; but the loss of material in the process was so great, that the subsequent improvements superseded its use. Under one part of this patent, the distillation was carried on sometimes with the air partially excluded from the apparatus, by means of the vapor of water, sometimes without, the low evaporating point of the cocoa-nut acids rendering the exclusion of air a matter of much less importance than when distilling other fat acids." At this time, in conjunction with Mr. Jones, Mr. Wilson appears to have first tried using the vapor of water to exclude the air from the apparatus during distillation. This led, in 1842, E. Price and Co. to patent, in the names of Wilson and Jones, which involved the treatment of fats, previously to distillation, with sulphuric acid, or nitrous gases. M. Frémy, in his valuable paper in the "Annales de Chimie," describes treating oils with half their weight of concentrated sulphuric acid, by which their melting point was greatly raised. He gave, however, particular directions that the matter under process should be kept cool. Instead of doing this, Mr. Wilson found it advantageous to expose the mixture of fat acid and fat to a high temperature, and this is still done at Price's works.

"Our process of sulphuric acid saponification was as follows:—Six tons of the material employed—usually palm oil, though occasionally we work cheap animal fat, vegetable oils, and butter, and Japan wax—were exposed to the combined action of 61 cwt's. of concentrated sulphuric acid, at a temperature of 550° F. In this process the glycerine is decomposed, large volumes of sulphuric acid are given off, and the fat is changed into a mixture of fat acids, with a very high melting point. This is washed, to free it from charred matter and adhering sulphuric acid, and is then transferred into a still, from which the air is excluded by means of steam. The steam used by us is heated in a series of pipes similar to those used in the hot-blast apparatus in the manufacture of iron, the object of heating the steam being only to save the small and reduce to a small extent gaseous loss in distillation." "We still," says the patentee, "employ this process, and in some cases reduce the quantity of acid employed to 4 lbs. and even 3 lbs. to a cwt. of the fat."

In 1854, Mr. Tighman obtained a patent for the exposure of fats and oils to the action
of water at a high temperature, and under great pressure, in order to cause the combination of the water with the elements of the neutral fats; so as to produce at the same time free fat acid and solution of glycerine. See GLYCERINE.

He proposed to effect this by pumping a mixture of fat and water, by means of a force-pump, through a coil of pipe heated to about 612° F., kept under a pressure of about 2,000 lbs. to the square inch; and he states that the vessel must be closed, so that the requisite amount of pressure may be applied to prevent the conversion of water into steam. Mr. Wilson improved upon this process, by passing steam into fat at a high temperature; and by this process hundreds of tons of palm oil are now treated. The glycerine and fat distilled over together, but no longer combined; and the former, being separated, is subjected to a redistillation, by which it is purified. This distillation is effected by transmitting through the fat contained in an iron still, steam at about 600° or 700° F., heated by passing through iron pipes laid in a fire. The steam is transmitted till the oily matter is heated to about 350°; the vapors produced being carried into a high shaft by a pipe from the cover of the iron vessel. The hot oily matter is then run into another vessel made of brick lined with lead, and sunk in the ground, for the purpose of supporting the brick work under or against the internal pressure of the fluid. It has a wooden cover lined with lead, directly beneath which, and extending across the vessel, is a leaden pipe, 1 inch in diameter, having a small hole in each side, at every 6 inches of its length; and through this pipe is introduced a mixture of 1,000 lbs. of sulphuric acid, sp. gr. 1.8, and the same weight of water. The introduction of the mixture, which falls in divided jets into the heated fat, produces violent ebullition; and by this means the acid and fat are perfectly incorporated before the action of the acid becomes apparent by any considerable discoloration of the fat. As the ebullition ceases, the fat gradually blackens; and the matter is allowed to remain for 6 hours after the violent ebullition has ceased. The offensive fumes produced are carried off by a large pipe, which rises from the top of the vessel, then descends, and afterwards rises again into a high chimney. At the downward part of this pipe a small jet of water is kept playing, to condense such parts of the vapors as are condensable. At the end of the 6 hours above mentioned, the operation is complete, and the product is then pumped into another close vessel and washed, by being boiled up (by means of free steam) with half its bulk of water. The water is drained off, and the washing repeated, except that in the second washing the water is acidulated with 100 lbs. of sulphuric acid. The ultimate product is allowed to settle for 24 hours; after which it is distilled in an atmosphere of steam—once, or oftener,—until well purified, and the product of distillation is again washed, and after being pressed in the solid state, is applied to the manufacture of candles.

The following definitions of terms applied to candles are by Mr. Wilson:

Belmont Sperm.—Made of hot pressed, distilled palm acid.

Belmont Wax.—The same material tinged with gamboge.

Best Composite Candles.—Made of a mixture of the hard palm acid, and stearine of cocoa-nut oil.

Composite, Nos. 1, 2, and 3, are made of palm acids, and palm acids and cocoa-nut stearine, the relative proportions varying according to the relative market prices of palm oil and cocoa-nut oil at the particular time when the candles are manufactured.

Composite, No. 4. A description of candle introduced, at a price a very little above the price of tallow dip candles. They are somewhat dark in color, but give a good light.

The highest-priced candles are usually made in the ordinary mould; but at Price and Co.'s manufacture they have a machine for moulding the ordinary stearine candles, and others of a similar nature. When one set of candles is discharged from the mould, the moulds are re-wicked for the next process of filling. These moulds are arranged, side by side, eighteen in number, on a frame; and for each mould there is a reel capable of holding sixty yards of wick, enclosed in a box. The moulded candle, being still attached to the cotton wick, when it is forced out of the mould, brings the fresh wick into it. The moulded candles are, by a very ingenious contrivance, held firm in a horizontal position while a knife passes across and severs the wick. The wicks for the new set of candles are secured, by forceps, firmly to the conical caps of the moulds; these are carried into a vertical position, and slid upon a railway to a hot closet, where they become sufficiently warm to receive the fat, which, kept at the melting point by steam pipes, is held in a cistern above the rails; from this cistern the moulds are filled by as many cocks, which are turned by one impulse. If we imagine an extensive series of these sets of moulds travelling from the machine over a railway, in regular order, and that, when the fat has become solid, these return, the candles are discharged, and the process is renewed,—the machine will be tolerably well understood. Each machine holds about 200 frames of moulds, and each contains 18 bobbins, starting each with 60 yards of cotton wick.

Night-Lights.—These are short thick cylinders of fat, with a very thin wick, so proportioned one to the other, that they burn any required number of hours. The moulds in which these are made are metal frames, perforated with a number of rectangular holes, and having a movable bottom, with a thin wire projecting from it into every mould. These are
filled with melted fat, and, when cold, the bottoms are forced up, and all the cylinders of fat ejected, each having a small hole through which the wick, a cotton previously impregnated with wax, is inserted. This being done, the night-light, being pressed on a warm porcelain slab, is melted sufficiently to cement the wick. These night-lights are burned in glass cylinders, into which they fit.

*Child's Night-Lights* are melted fat poured into card-board boxes, which have a hole in the bottom, through which the wick and its metallic support are placed.

**CANES.** Canes of various kinds are employed in manufactures, as the Sugar cane, Bamboo canes, and Rattan canes, &c. The bamboo is a plant of the reed kind, growing in the East Indies, and other warm climates, and sometimes attaining the height of 60 feet. Old stalks grow to five or six inches diameter, and are so hard and durable as to be used for building, and for all sorts of furniture, for water-pipes, and for poles to support palanquins. The smaller kinds are used for walking-sticks, flutes, &c.

In 1856, we imported 599,000 Bamboo canes into England.

Rattan canes are often confounded with the Bamboo. They are, however, the produce of various species of the genus *Calamus*. They are cylindrical, jointed, very tough and strong, from the size of a goose-quill to that of the human wrist, and from fifty to a hundred feet in length. They are used for wicker-work, seats of chairs, walking-sticks, &c.

In 1856, we imported of Rattan canes, 7,840,762, (the computed value of which was £15,681.)

**CANGICA WOOD,** called also in England *Anpiga.* It is of a rose-wood color, is imported from the Brazils in trimmed logs from eight to ten inches diameter. As a variety in cabinet work, small quantities of this wood are employed.

**CANNABIC COMPOSITION.** This material, for architectural decoration, is described by Mr. B. Albano to have a basis of hemp, amalgamated with resinous substances, carefully prepared and worked into sheets of large dimensions. Ornaments in high relief, and with great sharpness of detail, are obtained by pressure of metal disks, and they are of less than half the weight of paper made ornaments, sufficiently thin and elastic to be adapted to wall surfaces, bearing blows of the hammer, and resisting all ordinary actions of heat and cold without change of form. Its weather qualities had been severely tried on the continent, as for coverings of roofs, &c., remaining exposed without injury.

This composition is of Italian origin, and in Italy it has been employed for panels, frames, and centres. It is well fitted to receive bronze, paint, or varnish, the material is so hard as to allow gold to be burnished, after gilding the ornaments made of it.

**CANNEL COAL.** Cannel coal is obtained in Lancashire, in Derbyshire, in Warwickshire, and in Scotland, in considerable quantities; there are some other localities in which it is procured, but not so extensively. Its use as a fuel and for gas making will be found in the articles devoted respectively to these subjects.

This coal has a dark grayish black color, the lustre is glistening and resinous, it takes a good polish, and is hence made into a variety of ornaments. It is not equal to jet, (see Jet,) being more brittle, heavier, and harder; but cheap ornaments made ofannel coal are not unreasonably sold for jet; cannel coal is made up of horizontal layers, and has a grain somewhat resembling wood.

The coal, when worked for ornaments, is cut with a saw, and the pieces are rough-shaped with a chopper. For making a small box, whether plain, screwed, or eccentric turned, the *plank way*, or the surface parallel with the seam, is most suitable; it is also proper for vases, the caps and bases of columns, &c. Cylindrical pieces, as for the shafts of columns, should be cut from either edge of the slabs, as the laminating when run lengthways, and the objects are much stronger; cylindrical pieces thus prepared, say 3 inches long and 4 of an inch diameter, are so strong, they cannot be broken between the fingers. Similar pieces have been long since used for the construction of flutes, and in the British Museum may be seen a small box of cannel coal, said to have been turned in the reign of Charles 1, and also two busts of Henry VIII. and his daughter Lady Mary, carved in the same material. The planks of wood turn the most freely, and with shavings much like those of wood; the edges yield small chips, and at last a fine dust, but which does not stick to the hands in the manner of common coal. Flat objects, such as inkstands, are worked with the joiner's ordinary tools and planes. The edges of cannel coal are harder and polish better than flat surfaces.——*Hottapptel.* See Coal and Boghead Coal.

**CANNON** See Artillery.

**CAOUTCHOUC, GUM-ELASTIC, or INDIAN-RUBBER** (*Caoutchouc, Fr., Kautschuk* Federhars, Germ.) occurs as a milky juice in several plants, such as the *aphonia, cohues,* called also *hevea guianensis, caoutchouc, jatropha elastica, castilloja elastica, ocropus polleta, fleas religiosa and undina, terecularia elastica,* &c.

The juice itself has been of late years imported. It is of a pale yellow color, and has the consistence of cream. It becomes covered in the bottles containing it with a pellicle of concrete caoutchouc. Its specific gravity is 1.012. When it is dried it loses 55 per cent.
of its weight; the residuary 45 is elastic gum. When the juice is heated it immediately coagulates, in virtue of its albumen, and the elastic gum rises to the surface. It mixes with water in any proportion; and, when thus diluted, it coagulates with heat and alcohol as before.

I. CAOUTCHOUC MANUFACTURES.

But before entering upon their special divisions we may advert to some of the steps that have created this new employment for capital, commerce, and skill, especially as Mr. Hancock conceived it but just to the memory of the late Mr. Macintosh, to record the circumstances which led to his invention of the "Waterproof" double textures," that have been so long celebrated throughout the world by the name of "Macintoshes."

It will be recollected that, on the introduction of coal gas, the difficulties were very great to purify it from matters that gave a most disagreeable odor to the gas and gas apparatus; the nuisance of these products led to many inconveniences. Mr. Macintosh, then employed in the manufacture of culdair, in 1819 entered into arrangements with the Glasgow Gas Works to receive the tur and ammoniacal products. After the separation of water, ammonia, and pitch, the essential oil termed naphtha was produced, and it occurred to him that it might be made of use as a solvent for Indian-rubber, and by the quality and quantities of the volatile naphtha, he could soften and dissolve the Indian-rubber; after repeated experiments to obtain the mixtures of due consistency, Mr. Macintosh, in 1823, obtained a patent for water-proof processes, and established a manufacture of articles at Glasgow, and eventually, with partners, entered upon the extended scale of business at Manchester, now so well known as the firm of Charles Macintosh and Co.

The action of many solvents of Indian-rubber is first to soften and then to form a sort of gelatinous compound with Indian-rubber, requiring mechanical action to break the bulk so as to get complete solution, when the original bulk is increased twenty or thirty times to form a mass; it may be imagined that in the early trials much time was occupied, and manual labor, to break up the soft coherent mass, i.e., while hand-labor, sieves, the painter's slab and miller, and other simple means were resorted to.

Macintosh, Hancock, and Goodyear alike record the simple manipulations they first employed, and the impression produced at the last, when they compare their personal efforts with the gigantic machinery to effect the same results.

Mr. T. Hancock's first patent was in April, 1829: "For an improvement in the application of a certain material to various articles of dress and other articles, that the same may be rendered elastic." Thus, to wrists of gloves, to pockets, to prevent their being picked, to waistcoats, riding belts, boots and shoes without tying and lacing, the public had their attention directed. To get the proper turpentine to facilitate solution, and remedy defects of these small articles, and to meet the difficulties of practice and failures, Mr. Hancock gave constant zeal, and pursued the subject until, united with the firm of C. Macintosh and Co., he has been constantly before the world, and produced one of the most important manufactures known.

To get two clean pieces to unite together at their recently cut surfaces, to obtain facile adhesion by the use of hot water, to cut the Indian-rubber by the use of a wet blade, to collect the refuse pieces, to make them up into blocks, and then cut the blocks into slices, were stages of the trade which required patience, years of time, and machinery to effect with satisfaction to the manufacturers.

To operate upon the impure rubber was a matter of absolute necessity for economic reasons: the bottles made by the natives were the purest form, but larger quantities of rubber could be cheaply obtained, full of dirt, stones, wood, leaves, and earth. To facilitate the labor of cutting or dividing, Mr. Hancock resorted to a tearing action, and constructed a simple machine for the purpose. (See Fig. 140.) A shows the entrance for pieces of rubber; B, interior of fixed cylinder, with teeth; C, cylinder to revolve, with teeth or knives; D, the resulting ball of rubber.

This machine had the effect of tearing the Indian-rubber into shreds and small fragments by the revolution of a toothed roller; the esosthene yielded, became hot, and ultimately a pasty mass or ball resulted; when cooled and cut it appeared homogeneous. Waste cuttings put, in the first instance, on the roller, were dragged in, and there was evidence of action of some kind taking place; the machine was stopped, the pieces were found cohering together into a mass, this being cut showed a mottled grain, but being replaced and subjected to the revolving teeth of the rollers, it became very hot; and was found to be uniformly smooth in texture when cooled and cut open.

The first charge was about 2 ounces of rubber, and required about the power of a man to work it. The next machine soon formed a soft solid, with speed and power, from all kinds of scraps of Indian-rubber, cuttings of bottles, lumps, shoes, &c.; a charge of one pound gave a smooth uniform cylindrical lump of about 7 inches in length and 1 inch in diameter. This process, including the use of heated iron rollers, was long kept secret; it is known as the masticating process now, and the machines are called "Masticators." In
from when, it it still and cylinders and considered and thus the whole became a plastic mass. Instead of a wooden plank as the bed of the machine, a revolving iron cylinder was used, kept hot by steam or water, and the coated cloth passed over flat iron chambers, heated the same way, to evaporate the small quantity of solvent. Masticated rubber has been spread without any solvent by these machines; but the spreading is best effected by the rubber being in some degree softened by the addition of small quantities of the solvent.

Sheets of rubber have been prepared by saturating the cloth with gum, starch, glue, &c., then rubber dough was placed on this smoothed surface; sufficient coatings of the rubber were spread to make up the desired thickness, the cloth was immersed in warm water to dissolve the gum, when the sheet of rubber came off with ease, and the plastic, or dough state, was the precursor of vulcanization experiments and success.

The clamminess of caoutchouc is removed by Mr. Hancock in the following manner: 10 pounds of it are rolled out into a thin sheet between iron cylinders, and at the same time 20 pounds of French-chalk (silicate of magnesium) are sifted on and incorporated with it, by means of the usual kneading apparatus. When very thin films are required, (like sheets of paper,) the caoutchouc, made plastic with a little naphtha, is spread upon cloth previously saturated with size, and when dry is stripped off. Mixtures of caoutchouc so softened may be made with asphalt, with pigments of various kinds, plumbago, sulphur, &c.

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The first form of bags or pillows, or ordinary air-cushions, is well-known, and manufactured by C. Macintosh and Co. as early as 1825 and 1826; when pressure is applied they yield for the instant to the compressing body, and then become rigid, and the whole strain is borne by the inelastic material of the bag which then resolutely bears the strain. Mr. T. Hancock once tried an ordinary pillow between boards in a hydraulic press, and records that it bore a pressure of 7 tons before it burst. To remedy the evils of this form an ingenious arrangement was made of inserting slips of Indian-rubber into the fabric, so that it expanded in every direction. This yielding of the case, and divisions into strengthened partitions, enabled seats, beds, and other applications to be made. Particular details will be found in Hancock's patent for 1826.

The gas bags so commonly used appear, by Mr. Hancock's statement, to be made for experimental purposes in the year 1826; and in May, 1826, at the suggestion and for the use of Lieut. Drummond, they were employed in the Trigonometrical Survey, with the oxy-hydrogen jets of gas on balls of lime.

They were made strong and of rough materials—sustian made air-proof with thin sheet rubber. Mr. Hancock, to try whether the rubber was absolutely impervious to water, had a bag made and weighed it during 30 years; the decrease of weight is shown:

<table>
<thead>
<tr>
<th>Month</th>
<th>1826 Weight</th>
<th>lb. oz. drch.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct. 21st</td>
<td>1826</td>
<td>1 1 4</td>
</tr>
<tr>
<td>Oct. 25th</td>
<td>1827</td>
<td>1 1 2</td>
</tr>
<tr>
<td>Oct. 2d</td>
<td>1835</td>
<td>1 0 0</td>
</tr>
<tr>
<td>Nov.</td>
<td>1844</td>
<td>0 1 12</td>
</tr>
<tr>
<td>Oct.</td>
<td>1849</td>
<td>0 13 4</td>
</tr>
<tr>
<td>Feb.</td>
<td>1851</td>
<td>0 7 8</td>
</tr>
<tr>
<td>May</td>
<td>1854</td>
<td>0 3 14</td>
</tr>
</tbody>
</table>

In 1856 it was cut open and weighed 

It was quite dry. Thus 12 oz. of water had evaporated or escaped in a quarter of a century, and 15 oz. 8 dr. in 30 years of observation.

He remarks that bags of such cloth made with a thin coating of rubber, soon evaporated sufficient water to cause mildew, when laid upon each other; but this slow evaporation does not interfere with their ordinary applications.

The porosity of caoutchouc explains the readiness with which it is permeated by different liquids which have no chemical action upon it. Thin sections of dry caoutchouc of the best kind absorb from 18 to 26 per cent. of water in the course of a month, and become white from having been brown.

To enumerate the applications of these double fabrics for cushions, life-preservers, beds and boats, would be out of place here, however important and ingenious the plans. Thus, instead of one bag, several tubes or compartments gave the required form, and this again may be divided into cells, very small, and kept apart by wool or hair; of the advantage of this plan to divide the air spaces there can be no doubt.

For single texture fabrics, or cloth with one side only prepared, the process is the same as that described for double fabrics, only that one side is proofed, or covered with Indian-rubber solution or paste; and this kind of water-proof has an advantage over the old, that the surface worn outside, being non-absorbent, inhibits no moisture and requires no drying after rain or wear. The objection to single texture fabrics, of being liable to decomposition by the heat of the sun and from close packing, has been obviated by a discovery adopted by Messrs. Warne and Co., termed by them the Sincalor process, (sine calore, without heat) by which the properties of the rubber are so changed that heat, grease, naphtha, and perspiration, which decomposes the ordinary Indian-rubber water-proof, in no way affects the water-proof goods of the "Sincalor" process. The singular changes effected by this process are especially shown by the application of a hot iron to the surface, which destroys without the usual decompositions; the substance is burnt but is not rendered sticky. The process is stated to be secret.

II. Vulcanization.

Of all the changes effected by chance, observation, or chemical experiments of late years, few cases have been so important as the change in Indian-rubber by the process called Vulcanization. The union of sulphur with caoutchouc to give new properties so valuable, that it may be said the former well-known quality of elasticity is now rendered so variable that almost every range, from the most delicate tenacity to the hardness of metals, has been obtained at will by the manufacturer. These changes in the caoutchouc are produced with a degree of permanence to defy air, water, saline and acid solutions; the material is incapable of being corroded, and more permanent under usage than any other set of bodies in the world. Such are the results of the processes that induce a "change" in caoutchouc when sulphur and heat are employed; where metals and miner-
CAOUTCHOUC.

als are employed, "metallized" and "mineralized," "ionized," and a number of other terms have been used. When caoutchouc is mixed with sulphur from 2 to 10 per cent, and then heated to 270° and 300°, it undergoes a change, it acquires new character, its elasticity is greatly increased, and is more equable; it is not affected, nor is the substance altered by cold, no climate affects it, heat scarcely affects it, and when it does not become sticky and a viscid mess; if it yields to a high temperature it is to become harder, and will ultimately yield only at the advanced temperature to char and to decompose. All the ordinary solvents are ineffectual. The oils, grease, ether, turpentine, naphtha, and other solvents scarcely alter it, and the quantity of sulphur that will effect the change is known not to exceed 1 or 2 per cent. Further, if peculiar solvents, such as alkalis, remove all apparent sulphur from it, still the change remains; indeed, the analogy of steel to iron by the changes of condition effected by some small quantities of other bodies seems to be an analogous condition. Whatever the theory, which is exceedingly obscure, still the practice, by whatever name, is to obtain this changed state and exalted elastic properties.

"Vulcanization" had its discovery in America. Mr. Goodyear relates that, having made a contract for Indian-rubber mail bags, they softened and decomposed in service, and while he thought a permanent article had been made, the coloring materials and the heat united to soften and to destroy the bags; hence, by this failure, distress of all kinds arose, and the trade was at an end. During one of the calls at the place of abandonded macrature, Mr. Goodyear tried a few simple experiments to ascertain the effect of heat upon the composition that had destroyed the mail-bags, and carelessly bringing a piece in contact with a hot stove, it charred like leather. He called the attention of his brother, as well as other individuals who were present, and who were acquainted with the manufacture of gum elastic to the fact, as it was remarkable, and unlike any before known, since gum elastic always melted when exposed to a high degree of heat. The occurrence did not at the time appear to them to be worthy of much notice. He soon made other trials, the gum always charring and hardening. As ordinary Indian-rubber is always tending to adhere, many plans have been tried to prevent this. Chalk, magnesia, and sulphur had been patented in England and America, but no one seems to have supposed any other change would be produced by heat. Mr. Goodyear proceeded to try experiments, and produced remarkable results; samples of goods were shown about and sent to Europe. The late Mr. Brockedon, so well known for his talents and love of scientific investigations, had long pursued means to obtain a substitute for corks, and, after much ingenuity, had devised Indian-rubber stoppers. As soon as all mechanical difficulties were over, objections were taken to the color of the substance. Some samples of a changed rubber came into his possession, of which it was declared they would keep flexible in the cold, and were found not to have an adhesive surface. These caused numerous experiments, as it was recognized that a change had been effected, and although Mr. Brockedon failed, yet Mr. Hancock kept on working, combining sulphur, with every effect but that of vulcanization, as he was ignorant of the power of heat to effect this change. He used melted sulphur, and produced proof of absorption, for the pieces of caoutchouc were made, low throughout; by elevating the temperature he found they became changed, and then the lower end of slips "nearest the fire turning black, and becoming hard and horny," (the sulphur was melted in an iron pot.) By these simple observations, as they now seem, Mr. Goodyear in America and Mr. Hancock in England, were induced to take out patents, and commence that series of manufacturing applications to which there seems no limit. The first English patent was by Mr. Hancock. The general method is to incorporate sulphur with caoutchouc, and submit it to heat; if any particular form is required, the mixture is placed in moulds, and takes off any delicate design that may be upon the iron or metal mould, and if these are submitted to higher degrees of heat, the substance and evolved gases expand, and thus a very hard, horny, or light but very strong substance is produced, called hard Indian-rubber, or "vulcanite." Mouldings, gun-stocks, combs, cabinet work, and hundreds of forms may be obtained by these curious means. The term vulcanization was given by Mr. Brockedon to this process, which seems by the employment of heat and sulphur to partake of the attributes of the Vulcan of mythology. For the "change" or "vulcanizing" to get a yielding but permanent elasticity, steam heat is usually employed in England, but in America, ovens, with various plans for producing dry heat, are generally employed. The articles thus made being more elastic, unaffected by heat, cold, or solvents, attracted much attention, and Mr. Parke was engaged to find out a method of producing the same effects now secured by patent: all ordinary means were used and given up, but he finally succeeded. The process of cold sulphuring of Mr. Parke consists in plunging the pieces of caoutchouc in a mixture of 100 parts of sulphur of carbon, and 24 parts of protochloride of sulphur, for a minute or two, and then immersing them in
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cold water. Thus supersulphuration is prevented in consequence of decomposing the chloride of sulphur on the surface by this immersion, while the rest of the sulphur passes into the interior by absorption. Mr. Parkes prescribes another, and perhaps a preferable process, which consists in immersing the caoutchouc in a closed vessel for 2 hours, containing a solution of polysulphuret of potassium indicating a density of 25° Beaumb at the temperature of 248° Fahr.; then washing in an alkaline solution, and lastly in pure water. A uniform impregnation is thus obtained.

In the first instance sulphur, caoutchouc, and heat were alone employed. The temperature and the time to which the mixtures are subjected to heat afford conditions to be best understood by the practical man. Vulcanized rubber now is not only the changed substance as produced by sulphur, but it contains metallic oxides, &c. Metallic and mineral substances, and these compounds, are perhaps much better fitted for their respective uses than the pure sulphur and Indian-rubber. White lead, sulphuret of antimony, black lead, and other substances enter into these combinations. After the early experiments with vulcanized rubber, there seemed reason to believe that changes slowly took place. The rubber was found to become brittle, and bands stretched out broke immediately. To a great extent this has been remedied by the use of lead, which seems to combine with the sulphur, for changes are believed by practical men to take place with pure elastic vulcanized caoutchouc, which do not occur when metallic matters are duly mixed. This is a trade statement, which may be true for some special uses. The brittleness may perhaps more fairly be admitted to be due to inexperience, and the difficulties to meet the demands of the public for a new article; but to those whom it may most concern, we have raised this question so far as to obtain the conscientious opinion of Mr. Thomas Hancock, (now retired from business,) who considers that by the peculiar plan of vulcanizing by a bath of sulphur, and employing high-pressure steam, (described in Patent of 1843,) he obtains what he calls pure vulcanizing, that is, the use of sulphur, rubber, and heat. He states "That by this mode, the greatest power or extent of extensile elasticity is obtained, and that this quality is diminished in proportion as other matters are present in the compound." It may, however, be useful to record some of the results of early trials made by competent authorities, with the view of testing its ultimate employments. Mr. Brockedon stated at the Institution of Civil Engineers, that he had kept vulcanized Indian-rubber in tranquil water for 14 years without visible change, and he summed up the then knowledge of trade production, that there was perhaps no manufacturing process of which the rationale was so little understood as that of vulcanizing caoutchouc; all was conducted on the observation of facts, a given quantity of sulphur to a certain thickness of rubber, at a certain temperature; and certain results were reckoned upon with confidence, but more from practice than theory. Mr. Brockedon had placed vulcanized rubber for 10 years in damp earth, and it exhibited no change.

When articles were moulded, the metal of the mould was not a matter of indifference; if cold, the article was usually delivered perfectly clean, but if of brass or copper, then the material adhered to it, probably from the greater affinity of the sulphur for the metal than for the caoutchouc: these surface effects may well be borne in mind, for it appears not to be an easy matter to vulcanize large masses of caoutchouc, while sheets and thin films are readily changed. The soft masses of materials are placed in moulds, strongly secured, if a high temperature is to be used, and the mass comes out with the form thus given to it, and more or less elastic; hence the surface of a mass is almost always likely to be advanced in the vulcanizing changes.

At present, a very large proportion of the articles made have the forms given to them in the plastic state, and then subjected to heat; the change is effected, and they retain their form, although rendered permanently elastic.

Mr. Brockedon and Mr. Brunel tried this substance on the Great Western Railway in place of felt, to be used between the under sides of bearing rails and sleepers of railways. It appeared, by constant trials of nearly a year, to be quite indestructible to any action to which it had been exposed; the slips were indented by the edge of the rail, but not permanently so, and the surface was glazed, as if by friction; the slips were 6 inches wide, and weighed 8 oz. to the yard in length; the transit of the carriages was easier over that part of the line.

To test the power of endurance to heavy blows, Mr. Brockedon subjected a piece of vulcanized Indian-rubber, 1½ inches thick and 2 inches area, to one of Nasmyth's steam hammers of 5 tons; this first rested on the rubber without effect, then was lifted 2 feet and dropped upon it without injury, then lifted 4 feet, the vulcanized cake was torn, but its elasticity was not destroyed. Still more severe trials were made: a block of vulcanized caoutchouc was placed as between cannon balls, with the whole power of the heaviest steam hammers employed, but the iron spheres split the block, and the elasticity of the vulcanized caoutchouc was not destroyed.

The natural and the vulcanized rubber have both been proposed as absolutely resisting the power of shot and rifle balls. Instructive cases are known of projectors offering to be clothed in their own cuirasses, and meet the charge of a fired rifle; when a deal board or log
of mutton has been substituted in the interior, they have been found perforated by the rifle-ball, while back and from the cuirass showed no change, the truth being that the bullet cut its way through, and the edges of the aperture closed and joined, so that, no hole being visible, led to the conclusion that the ball had declined to penetrate the rubber.

Among the applications may be named the construction of boats and pontoons. On the first trial in the Arctic regions, they were adopted to give possible conveyance when other boats could not be carried; the Indian-rubber boat soon won its character; it took the icy channels, and bore the brunt of all collisions, and without damage met rock, and ice, and storm, where it was believed no other boat could live. Since then, they have been employed on the rivers of Africa by missionaries and travellers, and on lakes in England.

Sheets of enormous size,—ship-sheets,—have been made 50 yards long, and 66 inches wide, others, 10 feet square; these are proposed to pass over a steam-vessel’s side, to adapt a valve, fix a pipe, or repair, from the interior, the vessel itself without going into dock. These stout sheets, 1/2 inch thick, are let down by ropes over a ship’s side, and brought over the hole or place for repair by the pressure of the water on the elastic sheet, the leak may be stopped and the ship pumped dry, pipes renewed, shot-holes and leaks stopped. Indeed, an early application of compounds of native rubbers and other materials was applied directly as sheathing for ships with success; but litigation among the parties caused the business to cease. Since the various plans for getting a flexible material have been successful, there seems no doubt but many unexpected applications will be made.

Mr. Goodyear sums up the advantages of vulcanized rubber under the following heads, as being either properties new, or superior to those possessed by the natural caoutchouc:—

3. Durability. 10. Facility of being ornamented by painting, bronzing, gilding, japanning, and mixing with colors.
5. Unalterability by climate, or artificial heat, or cold. 12. Odor.
6. Inadhesiveness. 7. Impermeability to air, gases, and liquids.

We are indebted for the following facts and remarks to Messrs. Silver and Co., of London and Woolwich:

The chief improvements operated in caoutchouc by the process of vulcanization, are the properties of resisting and remaining unaffected by very high degrees of heat and cold, and increased compressibility and elasticity. In its natural state, Indian-rubber becomes rigid by exposure to cold, and soft and plastic by heat, under the action of boiling water. Articles manufactured of this substance suffer and lose the qualities which constitute their value in cold and in hot countries. A piece of Indian-rubber cloth, for instance, taken to Moscow in December or January, would assume all the qualities of a piece of thin sheet iron, or thick pasteboard; the same cloth would in India or Syria become uncomfortably pliable, and present a moist and greasy appearance; and, indeed, after being folded up some time, it will be found to be glued together. Nothing but vulcanization insures the equable condition of the articles in the most intense cold, and, in heat up to and above 50°, makes Indian-rubber fit for practical purposes. These advantages have conduced to its being very extensively used in connection with machinery of every description; and as steam power is still further employed, and as the numerous other advantages possessed by vulcanized Indian-rubber become known, (for it is only of late that any idea of their extent has been realized,) its application will be extended and proportionally its consumption increased.

The compressibility and the return to its former dimensions, when the pressure has ceased, in one word, the elasticity of the Indian-rubber, is increased to such a degree by vulcanization, that comparing the improved with the original article, it may be said that the native Indian-rubber is almost devoid of elasticity. The high degree of elasticity which it obtains by vulcanization is shown by the results of the following experiments, in which a block of the vulcanized Indian-rubber, of the kind used for the manufacture of railway car-
riage springs, measuring 6 inches outside disk, 1 inch inside disk, and 6 inches deep, was taken and exposed to pressure:—

A pressure of \( \frac{1}{2} \) ton reduced it to

<table>
<thead>
<tr>
<th>Ditto</th>
<th>Ditto</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5(\frac{1}{16}) in. deep.</td>
</tr>
<tr>
<td>1(\frac{1}{2})</td>
<td>5(\frac{1}{16}) do.</td>
</tr>
<tr>
<td>2</td>
<td>4(\frac{1}{16}) do.</td>
</tr>
<tr>
<td>2(\frac{1}{2})</td>
<td>3(\frac{1}{16}) do.</td>
</tr>
<tr>
<td>3</td>
<td>3(\frac{1}{16}) do.</td>
</tr>
<tr>
<td>3(\frac{1}{2})</td>
<td>3(\frac{1}{2}) do.</td>
</tr>
<tr>
<td>4</td>
<td>3 do.</td>
</tr>
</tbody>
</table>

The block was left under pressure for 48 hours, and in each case returned to its original dimensions after a short period when the pressure was removed.

Indian-rubber and canvas hose are now generally used where leathern pipes were used in former times, viz. wherever a flexible tube is required, in fact, where it is not possible to use a metal pipe. The advantages which the Indian-rubber and canvas hose has over the leathern pipe, are, that it does not require draining and greasing after being used, that it can be left in the water without rotting, and that it does not freeze in cold weather. Leathern pipes, on the contrary, require the most careful treatment, and even with the greatest care they are liable to frequent leaking. Indian-rubber and canvas hose are made to resist atmospheric and hydraulic pressure, say up to 1,000 lbs. pressure on the square inch. Of this Indian-rubber and canvas hose, the descriptions mostly in use are the following:—

1 Ply which will stand a pressure of about. - 20 lbs. to square inch.
2 Ply for conducting water “ 30 to 40 “
2 Ply stout “ 75 “
3 Ply for brewers, &c. “ 175 “
4 Ply for steam and fire-engines “

Among the most recent uses of Indian-rubber and canvas, are those of its manufacture into gas and ballast bags; the former are used for the transport of gas, and applied to the various emergencies of gas engineering. Indian-rubber gas tubing is now in general use, the great advantage over metal tubes being the ease with which gas can be conveyed to whatever part of the building it may be required; this, where any alterations are being effected, is a great desideratum. Ballast bags, large ston bags of Indian-rubber and canvas, capable of holding from 1 to 5 or 10 tons of water, are coming into use as the most convenient form of ballast, thus saving valuable space, which is made available for cargo. These bags may be emptied at any time, and when flattened down and rolled up, they can be stowed away. Indian-rubber bags for inflation have also in a few cases been made use of for buoying up vessels, but hitherto the practice has been experimental only, and such floating machines are not as yet generally in use.

The vulcanizing Indian-rubber on silk or woollen was for a long time considered impracticable, because the process of vulcanization destroyed the fibre and texture of the two substances; and it is stated that now this process is effected in a manner which deprives neither silk nor wool of their natural qualities and strength. By this improvement, combined with Silver's patent process of annihilating the unpleasant smell which all Indian-rubber goods used to acquire in the process of manufacture, the advantages of that substance for clothing purposes are extended to the lightest and the warmest of our textures. Silk and Indian-rubber garments are made without any deterioration of the strength and durability of the stuff, while they are perfectly free from odor of any kind. (See page 302.)

**III. MECHANICAL APPLICATIONS OF CAOUTCHOUC.**

Numerous important applications of caoutchouc have been made in the mechanical arts, among which we may mention springs for railway and common road carriages, military carriages, lifting springs for mining ropes and chains, towing ropes and cables, rigging of ships, recoil of guns on ships, the tires and axles of railway and other wheels, to axles and axle bearings, to windows of railway carriages, railway switches, beds of steam-hammer, couplings for locomotives and tenders, packing for steam and water joints, shields for axle boxes, sockets for water pipes, bands for driving machinery, valves for pumps, tubes for conveying acids, beer, water, and other fluids, packing for pistons.

Many of these improvements have been the subject of patents, a list of the principal of which is given, stating the name of patentee, date, and object of so much of patent as relates to the use of caoutchouc.
## List of Patents.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name.</th>
<th>Date.</th>
<th>Object of Patents.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lacey</td>
<td>29th Mar., 1825</td>
<td>Indian-rubber springs for carriages enclosed in cases with dividing plates.</td>
</tr>
<tr>
<td>2</td>
<td>Melville</td>
<td>13th April, 1844</td>
<td>Springs for buffers and bearing; sphere of Indian-rubber and air, with dividing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>plates, and enclosed in iron cases.</td>
</tr>
<tr>
<td>3</td>
<td>Walker and Mills</td>
<td>3d July, 1845</td>
<td>Buffers, Indian-rubber bags, enclosing air, in iron cases.</td>
</tr>
<tr>
<td>4</td>
<td>W. C. Fuller</td>
<td>23d Oct., 1845</td>
<td>Buffer and bearing springs of Indian-rubber, cylindrical rings with dividing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>plates of iron.</td>
</tr>
<tr>
<td>5</td>
<td>Adams and Richardson</td>
<td>24th May, 1847</td>
<td>Elastic packing for axles.</td>
</tr>
<tr>
<td>6</td>
<td>C. De Bergue</td>
<td>26th July, 1847</td>
<td>Indian-rubber buffer, bearing and draw springs.</td>
</tr>
<tr>
<td>7</td>
<td>Wrighton</td>
<td>2d Dec., 1847</td>
<td>Indian-rubber shield for axle box.</td>
</tr>
<tr>
<td>8</td>
<td>C. De Bergue</td>
<td>5th Jan., 1848</td>
<td>Anti-recoil buffers of Indian-rubber, and improvements in dividing plates.</td>
</tr>
<tr>
<td>9</td>
<td>Normanville</td>
<td>2d May, 1848</td>
<td>Indian-rubber shield for axle box.</td>
</tr>
<tr>
<td>10</td>
<td>C. De Bergue</td>
<td>16th April, 1850</td>
<td>Station buffers of Indian-rubber, and carriage buffers.</td>
</tr>
<tr>
<td>11</td>
<td>P. R. Hodge</td>
<td>8th Mar., 1852</td>
<td>Packing for steam joints.</td>
</tr>
<tr>
<td>12</td>
<td>G. Spencer</td>
<td>2d Feb., 1852</td>
<td>Indian-rubber cones as buffer, bearing, and draw springs.</td>
</tr>
<tr>
<td>13</td>
<td>P. R. Hodge</td>
<td>8th Mar., 1852</td>
<td>Indian-rubber compound springs, Indian-rubber to wheel naves, and to axle box</td>
</tr>
<tr>
<td>14</td>
<td>W. Scott</td>
<td>8th Mar., 1852</td>
<td>Indian-rubber as check springs, wheel nabe, suspensor springs.</td>
</tr>
<tr>
<td>15</td>
<td>J. E. Coleman</td>
<td>2d June, 1852</td>
<td>Indian-rubber applied to buffer, bearing, and draw springs, rails, chairs, and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>sleepers, wheel tires, windows, axle bearings, plumber blocks, connecting rods,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>steam hammer beds.</td>
</tr>
<tr>
<td>17</td>
<td>C. De Bergue</td>
<td>28th Mar., 1853</td>
<td>Indian-rubber bearing springs. (Patent refused.)</td>
</tr>
<tr>
<td>18</td>
<td>G. Spencer</td>
<td>2d July, 1853</td>
<td>Improved cones for buffer, bearing and draw springs.</td>
</tr>
<tr>
<td>19</td>
<td>R. E. Hodges</td>
<td>2d Nov., 1854</td>
<td>Improvements in fastening Indian-rubber springs.</td>
</tr>
<tr>
<td>20</td>
<td>G. De Bergue</td>
<td>4th Mar., 1854</td>
<td>Buffers for railways.</td>
</tr>
<tr>
<td>21</td>
<td>W. C. Fuller</td>
<td>10th May, 1854</td>
<td>Indian-rubber springs applied to anchors, cables, towing ropes, deck ropes.</td>
</tr>
<tr>
<td>22</td>
<td>E. Land</td>
<td>18th Aug., 1854</td>
<td>Indian rubber to feed-pipe, coupling and water joints.</td>
</tr>
<tr>
<td>23</td>
<td>W. C. Fuller</td>
<td>10th Jan., 1855</td>
<td>Indian rubber to steam common roads.</td>
</tr>
<tr>
<td>24</td>
<td>E. Miles</td>
<td>12th Jan., 1855</td>
<td>Indian-rubber to water-pipe couplings.</td>
</tr>
<tr>
<td>25</td>
<td>G. Richardson</td>
<td>28th Nov., 1855</td>
<td>Indian-rubber buffers with Spencer's cones.</td>
</tr>
<tr>
<td>26</td>
<td>W. Scott</td>
<td>14th May, 1856</td>
<td>Indian-rubber to axles and tires of wheels.</td>
</tr>
<tr>
<td>27</td>
<td>G. Spencer</td>
<td>25th July, 1856</td>
<td>Indian-rubber to feed-pipe, couplings for locomotives and tenders.</td>
</tr>
<tr>
<td>28</td>
<td>R. Eaton</td>
<td>20th Nov., 1856</td>
<td>Indian-rubber springs for railways.</td>
</tr>
<tr>
<td>29</td>
<td>R. Eaton</td>
<td>8th Dec., 1856</td>
<td>Indian-rubber springs in thin lamina for buffer, bearing, and draw springs, and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>lifting purposes.</td>
</tr>
<tr>
<td>30</td>
<td>H. Bridges</td>
<td>14th Mar., 1857</td>
<td>Spencer's cones applied to wood blocks in buffers, bearing springs, &amp;c.</td>
</tr>
<tr>
<td>31</td>
<td>J. Williams</td>
<td>11th Nov., 1857</td>
<td>Indian-rubber springs applied to the side or safety chains of trucks, &amp;c.</td>
</tr>
<tr>
<td>32</td>
<td>W. E. Nethersole</td>
<td></td>
<td>Do. do. do.</td>
</tr>
</tbody>
</table>
We have been at some pains to ascertain the progress that has been made in the practical application of these inventions, and notice them below, under the several heads mentioned above.

Springs.—The first proposal to use caoutchouc for springs that we are aware of, occurs in Lacey's patent (see list) in 1825, when blocks of caoutchouc were proposed to be used, having dividing plates of iron between each series; but little seems to have been done towards any practical application at that time: later in 1844, (see list,) Melville proposed to use spheres of caoutchouc, enclosing air, and separated by disks of wood or metal, the whole being enclosed in iron cases, and used for buffers and bearing springs for railway carriages. In 1845, (see list,) Walker and Mills proposed to use bags of caoutchouc enclosing air, and contained in cases of iron, for use as buffer springs.

The next improvement is contained in Fuller's patent of 1845, which consists in the use of cylindrical rings of vulcanized Indian-rubber, in thicknesses varying from 1/4 to 3 inches, and with diameter of ring suitable to the power of spring required; between each of these cylindrical rings he places a thin iron plate, through a hole in the centre of which passes a guide rod. Fig. 141 shows Fuller's spring in section and plan. These springs have been extensively used as buffer, bearing, and draw springs for railway uses alone and in combination with Bergue's improvements: some defects have been found in practice in this form, to obviate which, the ingenuity of later inventors has been exercised; the defects alluded to are, the tendency to swell out at the central unsupported part of the ring, thus from the undue tension rendering it liable to break under sudden concussion, and occasioning complete disintegration of the material where not breaking.

To obviate these defects, George Spencer (see list, Nos. 12, 18) proposed to mould the caoutchouc at once in the form it assumes under pressure, and then to place a confining ring of iron on the larger diameter. (See fig. 142.) By this ingenious plan, the caoutchouc loses its power of stretching laterally, being held by the ring b, secured in a groove moulded in the cone to receive it; when the pressure is applied to the ends, the rubber is squeezed into the cup-like spaces c, and thus the action of the spring is limited. By this plan, rubber of a cheaper and denser kind can be used than on the old cylindrical plan, and the patentee states that many thousands of carriages and trucks are fitted with these springs which give entire satisfaction; among which, are those on the Brighton, South-Western, North London, South Wales, Vale of Neath, Bristol and Exeter, Taff Vale, Lancashire and Yorkshire, St. Helen's, Bombay and Baroda, Theiss Railways, and many others. These cones are used as buffer, bearing, and draw springs for railway carriages, and are made in several sizes to suit various uses. To show the power that such
springs are equal to, we append the result of an experiment on a No. 1 cone, (for inside buffers,) 3 inches in length, $\frac{3}{4}$ inches diameter at ring, 5 inches diameter of ring.

1st Experiment, without the confining ring, weight of cone $1\frac{1}{4}$ lbs.

<table>
<thead>
<tr>
<th>Without any pressure the cone measured</th>
<th>Inches</th>
<th>Giving a stroke of</th>
</tr>
</thead>
<tbody>
<tr>
<td>With pressure—280 lbs.</td>
<td>$2\frac{1}{2}$</td>
<td>$\frac{1}{2}$ inch.</td>
</tr>
<tr>
<td>&quot;—448 lbs.</td>
<td>$2$</td>
<td>$1$ &quot;</td>
</tr>
<tr>
<td>&quot;—672 lbs.</td>
<td>$1\frac{1}{2}$</td>
<td>$1\frac{1}{4}$ &quot;</td>
</tr>
</tbody>
</table>

2d Experiment.

With the confining ring $b$, on the same double cone, the following were the results:—

<table>
<thead>
<tr>
<th>Without any pressure the cone measured</th>
<th>Inches</th>
<th>3 inches, as before.</th>
</tr>
</thead>
<tbody>
<tr>
<td>With—448 lbs.</td>
<td>&quot;</td>
<td>$2\frac{1}{2}$ &quot;</td>
</tr>
<tr>
<td>With—1,680 lbs.</td>
<td>&quot;</td>
<td>$2&quot;</td>
</tr>
<tr>
<td>With—2,912 lbs.</td>
<td>&quot;</td>
<td>$1\frac{1}{2}&quot;</td>
</tr>
<tr>
<td>With—15,680 lbs.</td>
<td>&quot;</td>
<td>$1\frac{1}{2}$ &quot;</td>
</tr>
</tbody>
</table>

The advantages are stated to be, less first cost than steel; less weight, 6 cwt. being saved in each carriage by their use; and great durability.

Coleman's improvement (see list, No. 15) consists in the use of iron rings to confine the lateral swelling of Indian-rubber cylinders. (See fig. 143.) They are used as bearing springs for engines and tenders on the North-Western railway, by J. E. M'Connell, Esq., who prefers them to steel, as being easy in action, durable, safe, and easy of repair; they are used also as buffers and draw-springs, but not to the extent of Fuller's and Spencer's form. To give an idea of the power of such a spring, we append the result of an experiment of one that we witnessed at Messrs. Spencer and Co.'s.

Experiments with one of Coleman's cylinders with and without the rings. Cylinder 6 inches long, 6 inches diameter, 1 inch hole, weight 9 lbs.

<table>
<thead>
<tr>
<th>Tons pressure.</th>
<th>Without the confining rings</th>
<th>With the 2 confining rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Inches Length.</td>
<td>Inches Length.</td>
</tr>
<tr>
<td>$\frac{1}{2}$</td>
<td>$6$</td>
<td>$5\frac{1}{16}$</td>
</tr>
<tr>
<td>1</td>
<td>$5$</td>
<td>$5\frac{11}{16}$</td>
</tr>
<tr>
<td>$1\frac{1}{2}$</td>
<td>$4\frac{1}{2}$</td>
<td>$5\frac{1}{2}$</td>
</tr>
<tr>
<td>2</td>
<td>$4\frac{1}{2}$</td>
<td>$5\frac{1}{2}$</td>
</tr>
<tr>
<td>$2\frac{1}{2}$</td>
<td>$3\frac{1}{2}$</td>
<td>$5\frac{1}{2}$</td>
</tr>
</tbody>
</table>

The next form of these springs is R. Eaton's, (see fig. 144; and list, Nos. 28, 29.) This
CAOUTCHOUC.

spring seems to be peculiarly adapted to use where a powerful spring, acting through a small space, and taking little room, is required, as for use in mining ropes and chains, (see Safety Cage;) iron ropes, for ship-rigging, for engine-springs, station buffers, and powerful draw-springs. Eaton's main idea is the use of laminae of Indian-rubber, of a maximum thickness of \(\frac{3}{8}\) an inch, with dividing plates, as in Lacey's and Fuller's, which avoids the objections stated above, by supporting the Indian-rubber at smaller intervals; for springs, where great power is wanted in little compass, and to act through short distances,—as in engine bearing-springs, lifting springs, and some kinds of draw-springs,—this form proves to be well suited. We give below the result of one such spring of the following dimensions; the spring was built up of 24 laminae, \(\frac{3}{8}\) of an inch thick, 4\(\frac{1}{2}\) inches square, with a thin iron plate between each, and a hole of one inch diameter for the guide rod through all; this, and several of the other experiments were made in a press of great delicacy and power, constructed for Messrs. Geo. Spencer and Co., for the purpose of testing such springs, at their office, in Cannon Street West, London, (see Proving Machines.)

<table>
<thead>
<tr>
<th>Tons</th>
<th>Length including plates,</th>
<th>Area of spring, 19 square inches,</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8(\frac{1}{2})</td>
<td>8(\frac{1}{2})</td>
</tr>
<tr>
<td>1(\frac{1}{2})</td>
<td>7(\frac{1}{2})</td>
<td>7(\frac{1}{2})</td>
</tr>
<tr>
<td>2(\frac{1}{2})</td>
<td>7(\frac{1}{2})</td>
<td>7(\frac{1}{2})</td>
</tr>
<tr>
<td>3(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
<tr>
<td>4(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
<tr>
<td>5(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
<tr>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
<tr>
<td>7(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
<tr>
<td>8(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
<tr>
<td>9(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
<tr>
<td>10(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
</tbody>
</table>

Hodge's compound spring (No. 13) is designed to obviate the frequent breakage of the steel springs on locomotive engines. Fig. 145 shows one of these springs; a block of Indian-rubber is placed on each end of the steel spring, or is suspended under the engine frame; they are in use on several of the English railways, and are said to answer the purpose intended well.

Scott's patent (see fig. 146; and list, No. 14) consists in the use of blocks of Indian-rubber, or cones, placed over the centre of spring; they are to obviate the danger of overloading carriages and trucks, a frequent source of danger to the springs, and are made to take the whole load in case of a spring breaking; they are in use on the Brighton and Crystal Palace Railway, Eastern Counties, Bombay and Baroda, and others. The same patentee has several ingenious applications of Indian-rubber to carriages to wheel tires, to the boxes of wheels, to shackle pins, and to the axle.

Bridges' Patent.—(See list, No. 30, fig. 147.) This inventor proposes to use Spencer's cones in blocks of wood, instead of iron confining rings. A series of them are enclosed in a case formed in the side timbers of the underframe of the railway truck or carriage; the cup space is formed in the block of wood, as our figure shows, and no guide rods are
required: the same principle is applied to draw and bearing springs. The advantages proposed by this arrangement are, the dispensing with guide rods and the taking the ultimate blow on blocks of wood, which deadens its effect; they are said to answer very well, and are used almost exclusively on the South Western and Bristol and Exeter Railways.

In 1847, Mr. De Bergue patented some improvements in the application of Fuller’s spring to buffer, bearing, and draw springs for railway uses.

Mr. Fuller’s Patent.—The applications for common road carriages, patented by Mr. Fuller of Bucklersbury in 1852 and 1855, have been extensively used, both in the form of cylindrical rings acting by compression and also of suspension springs for lighter kinds of vehicles.

Respecting these springs, figs. 148, 149, we have been furnished by the patentee with the following particulars:

The form generally used for heavy purposes, such as drays, vans, wagons, &c., consists of a series of rings of cylindrical or circular form, working on a perpendicular rod or spindle, on each side the axle, with the usual separating plates or washers: the depth and diameter of the rings being regulated by the weight to be sustained and the speed required.

During the late war, these springs were introduced by Mr. Fuller to the notice of the Government authorities at the Royal Arsenal, Woolwich, and were in consequence extensively adopted for all kinds of military carriages, store wagons, ammunition wagons, &c. They are also applied in the suspensory form for the medical cars and ambulance wagons for the wounded, for which purposes the use of Indian-rubber on the principle of extension is found to produce the easiest and most satisfactory spring hitherto discovered.

When the material is used as a suspension spring, the most advantageous form for the purpose is found to be round cord of the best and purest quality, prepared by solvents, and about ¼ or ½ inch diameter.

A continuous length of such cord is wound at a considerable tension over the ends of two metal sockets or rollers, in shape something resembling a cotton reel, and whilst in a
state of tension, bound at each end with strong tape or other suitable binding; the number of cords composing the spring, varying from 10 to 20, 30, or 40, according to the strength required.

Another important adaptation of Indian-rubber by Mr. Fuller, is that of anchor springs, towing ropes, and springs for the recoil of guns and mortars.

During the Russian war, about 120 mortar boats were constructed of light draught, each carrying a 15-inch mortar on a revolving pivot and platform in the centre of deck. It was considered desirable, if possible, to diminish the shock produced by the tremendous recoil of such heavy artillery on the deck of small vessels, and after a series of trials at Shoeburyness, which proved perfectly satisfactory, the plan was adopted of mounting each platform upon twenty powerful rings of Indian-rubber, the united force of which, at 1-inch deflexion, would resist about 400 tons. The performance of these mortar vessels at Swaborg, the Black Sea, and also subsequently in China, has been highly satisfactory; the intervention of this elastic material being found effectually to preserve the timbers of the vessel.

The application to towing ropes and anchor cables, has not yet been tried to an extent sufficient to test its merits; but it is universally admitted by engineers and practical men, that a powerful spring adapted to the chain cables of vessels when riding at anchor (acting on the principle of the buffer and draw-springs) would often prove of invaluable service in preventing the parting of the cable and its disastrous results.

In the list of patents, we have indicated the nature of several other improvements, which, being merely variations of the more important ones, we do not dwell on here.

Support for railway chairs.—Several proposals have been devised to this end, and a number of plans are given in Coleman's patent, 1852. He places the Indian-rubber under the chair, between the chair and rail, between the rail and sleeper. The plan has been only partially tried, but the proposer is very sanguine that the plan will prove useful.

Wheel tires.—Fig. 150 shows an important application to the tires of wheels for railway purposes. A thin band of Indian-rubber is inserted between the tire and spoke ring, by first covering it with a thin plate of iron, to protect the Indian-rubber while the hot tire is put on, when the wheel is instantly thrown into water and cooled. This has been severely tested for some time, and found to answer very well; the advantage gained, is the saving in the breaking and wear of the tires.

For windows.—Small ropes of Indian-rubber are inserted in grooves at each side of the window, and so stop out draught and prevent noise.

For steam-hammer beds.—A plate of Indian-rubber ½ thick, is placed under the bed of the hammer; the effect is greatly to diminish the transmission of shocks to the building, and to cheapen the foundation: as an instance of useful application, we may state, that at Messrs. Ransome and May’s works, at Ipwich, the working of the steam-hammer shook the building and windows to an alarming extent; but the insertion of blocks of vulcanized rubber under the anvil, almost entirely obviated these effects.

Joints between engines and tenders.—Messrs. Lund, Spencer, and Fenton have also
introduced the use of rings of this material to form a joint between the locomotive and tender. (P. 151.) They are extensively used, and entirely prevent the leakage common to the old ball and socket joints, and are much cheaper in first cost. Rings of Indian-rubber were proposed by Mr. Wickstead, for closing the socket joint of water pipes, and they are used in a variety of forms for that purpose.

Messrs. W. B. Adams, Normanville, Wrighton, and Hodge have also introduced the use of shields and rings of Indian-rubber for keeping the backs of axle boxes tight, so as to prevent the escape of the grease or oil, or the entry of dust and dirt.

A large trade has been established in the supply of bands of Indian-rubber for driving machinery; for many purposes they answer better than leather, water having no effect on them and there being little or no slip and fewer joints, they are made in all widths, and belts costing £1.50 each have been used in some cases. They are made with two or more layers of thread cloth between, and outside of which the rubber is placed.

As valves for steam and water pumps, Indian-rubber prepared to suit the use is also much used by all our large engine-makers. As tubes for conveying beer, water, and acid, Indian-rubber is also found to answer well, and is used largely. The tubes are made in all sizes and strengths, and the best are made by alternate layers of cloth and India-rubber. Very good tubes are also imported from America.

Another useful application of this material, is for the joints of steam and hot-water pipes; for this and similar purposes, a peculiar compound, known as Hodge's compound, is used. (Patent No. 11.) This consists in the mixture of cotton fibre with the rubber used for springs, known as the triple compound.

The success of these applications depends, of course, entirely on the composition being suitable to the various purposes to which they are applied; some being made to resist the effect of heat, others of acids, grease, and oils, the study of which has become an important element in the commercial adaptations of the various inventions enumerated.

IV. Solarization of Caoutchouc.

Singular as caoutchouc is in its properties and in its application, it is probable that, besides the mechanical and electrical qualities and general resistance to chemical action, it may yet be found to have other modifications peculiar and valuable. The practical men most conversant with this substance, and deeply involved with patents and successful manufactures, record their conviction of the influence of the solar light, and the marked distinctions supposed to exist between the influence of solar and terrestrial heat upon this substance.

Mr. Hancock says, "In my early progress, I found that some of the rubber I employed was very quickly decomposed when exposed to the sun: as the heat was never more than 90°, and rubber exposed to a much higher temperature was not injured by it, I suspected that light had some effect in producing this mischief. To ascertain this, I cut two square pieces from a piece of white rubber; one of these I colored black, and exposed it to the sun's rays; in a short time, the piece which had been left white was away, and the sharp angles disappeared; it seemed like the shape of a thin piece of soap after use; the blackened piece was not at all altered or affected. The lesson taught me by this experiment was of great value ever after."

Speaking of the annoyances and failures in the early Macintosh goods by heat, grease, &c., Mr. Hancock says, "The injurious effect of the sun's rays upon thin films of rubber we discovered and provided against before much damage accrued."

Mr. Goodyear says, "In anticipation of the future, as relates to a mode of treatment in manufacture, which, though lightly esteemed and little thought of now, I believe will be extensively practised hereafter, I feel bound to make a strong though qualified claim to the process of solarization. This process consists in exposing caoutchouc, when combined with sulphur, to the sun's rays." Again, "When exposed to the sun's rays for several hours, a change is produced, which may be called natural vulcanization, in all thin fabrics or thin sheets of caoutchouc." "Solarization is an effectual and cheap process of curing Indian-rubber." He further says, "It is well established that Indian-rubber melted at about 200° and in the sun's rays at 100° or less. Another effect yet more remarkable in the treatment of gum elastic, is that of the sun's rays upon it: when combined with sulphur and exposed to the sun, either in hot weather or cold, it becomes solarized, or divested of its adhesive quality; whereas, no other kind of light or heat has any similar effect, until the high degree of heat is applied to it, about 270°, which is used in vulcanizing."—Goodyear, p. 114, vol. I.

New Haven, U.S.

V. Trade Applications of Vulcanized Indian-Rubber.

Macintosh and Hancock give the following descriptions of their trade quality, to guide practical men; other manufacturers may also have similar scales of rubber.

A quality is the most elastic, it weighs about 60 lbs. per cubic foot, or 1/20 of a lb. per
CAPILLAIRE.

cubic inch, (this is understood to mean pure sulphur and caoutchouc, all other qualities are mixtures.)

3. quality weighs 82 lbs. per cubic foot, or \(\frac{1}{2}\) of a lb. to 1 cubic inch.

4. quality, more elastic than 3, weighs about 92 lbs. to the cubic foot, or \(\frac{14}{2}\) of a lb. to 1 cubic inch.

F. C. Fibrous compound, used for flange washers, valves, and pump-buckets, weight \(\frac{1}{2}\) of a lb. per cubic inch.

Many applications of caoutchouc can only be named. Surgical apparatus, and remedial adaptations for hospital purposes, would alone occupy great space; to call attention to the various ingenious contrivances, other information and specialties may be referred to the heads of Indian-rubber and vulcanite, or hard rubber, vulcanization, hose-pipes, pontoon, life-preserving apparatus, shoes, water-proof fabrics, washers for joints, valves for engines and pumps, elastic, endless, and driving bands. For hot and cold water valves this substance has been one of the most valuable applications to ocean steamers for many years.

The old mode of thread-making is now entirely obsolete, having given way to a new one rendered necessary by the introduction of vulcanized Indian-rubber, which now, for the purpose of thread-cutting, is always produced in the sheet by the spreading process before described, and of a thickness exactly agreeing with the width of the thread to be cut; that is, if No. 28 be required, which means, if 28 of the threads were spread side by side they would measure one inch; then the sheet is spread \(\frac{1}{2}\) of an inch in thickness, and consequently when 28 are cut out of the inch, square threads, i.e. threads with a rectangular section, are produced. The sheets are wound upon rollers, which are then fixed on centres in the lathe, and by means of a slide rest and a suitable knife, slices of the sheet are cut off, varying in thickness from \(\frac{14}{2}\) of an inch to \(\frac{1}{2}\), of an inch; and one of the greatest advantages of the vulcanized thread is the great length that can be cut; from a sheet of rubber wound upon a roller, hundreds of feet or yards may be cut at once into one continuous thread, whereas from the bottles the lengths were short, had to be joined, and differed in quality from each other.

Vulcanized thread is covered with silk and cotton; both are wound round it; the vulcanized thread is considerably more elastic than the native thread cut from bottles or sheets. Belts and bandages made from the vulcanized thread are very superior to the old sort, now completely obsolete.

The vulcanized rubber thread has lately been introduced into the Jacquard loom, by Messrs. Bonnet and Co., Manchester; the thread used is, by its elastic force, to supersede the use of the weights commonly employed, the number of which sometimes amounts to from two to three thousand in one loom.

In preceding editions, the names of Hancock and Goodyear were scarcely mentioned, yet for thirty-six years Mr. Hancock has labored to make a manufacture. For many years Messrs. Hancock and MacIntosh were alone in the trade, indeed until MacIntosh’s patent ceased, when the trade widened. His first patent was dated 1829, and the masticating machine was the foundation of the manufacture. Mr. Goodyear had his attention drawn to the subject by the manufacture of gum elastic in the United States, about 1831—2. Both have contributed to the literature of the art, (mingled with personal narratives, and trade affairs,) and it is presumed that, had the late Dr. Ure had their practical works before him, eulogistic mention would have been offered for past neglect. Both gentlemen’s patents are being worked by other men, and of the value of their processes, and the trade, some idea may be entertained when “The Scientific American” recently, while opposing the renewal of the terms for certain patents about to expire, gives the estimate of worth at 2,000,000 dollars for Chaffee’s patents, and Goodyear’s several patents are set at 20,000,-600 dollars. It is probable that the trade was not a really profitable one in America until about 1850. Of the value of the works in England and France of caoutchouc applications no adequate data appear. Of the facts involved in some of these patents, we may quote Mr. Hancock’s words, p. 106: “I think I might venture to state, not boastfully, but as a matter of fact, that there is not to this day, 1856, any document extant, (including those referred to in it,) which contains so much information upon the manufacture and vulcanization of rubber, as is contained in this specification. If any of my readers,” he goes on to say, “can point out such a document, I shall feel obliged if they will inform me of it.” This is the patent of 1848.

CAPILLAIRE. Originally a kind of syrup, extracted from maiden-hair. The term is now applied to a finely clarified simple syrup, which is made chiefly with orange-flower water.

CAPNOMORE. \((\text{C}_4\text{H}_2\text{O}_2[?])\) One of the substances discovered by Reichenbach in...
CARBOLIC ACID. 303

wood-tar. It appears to be a product of the metamorphosis of creosote under the influence of heat, or of the alkalies or alkaline earths. It has not been sufficiently examined to allow of its formula being considered as established. The above formula is founded on the analysis of M. Vellecle. When those oils from wood-tar which are heavier than water are treated with a strong potash lye, creosote and capnomore dissolve. Pure capnonore is not soluble in potash, but it appears to dissolve owing to the presence of creosote. When the alkaline solution is distilled, the capnonore comes over. (Vellecle.) It is more probable that the capnonore, instead of dissolving under the influence of the creosote, and subsequently distilling over with the water, is, in fact, produced by a decomposition of the creosote, for I have found that if the latter be long boiled with potash lye, it gradually diminishes in quantity, and finally almost disappears.

The density of capmonore is 0.995. It boils between 350° and 400°. This variation of the boiling point is indicative of a mixture.—C. G. W.

CAPRYLAMINE. (C8H13N.) A volatile base obtained by Squire, and also by Cahours, by acting on ammonia with iodide of capryle. It is homologous with methylamine, &c.—C. G. W.

CAPUT MORTUUM, literally, dead matter; a term employed by the alchemists to express the residuum of distillation or sublimation, the volatile portions having been driven off.

CARAMEL. Burnt or dried sugar, used for coloring spirits and gravies. It is a black, porous, shining substance, soluble in water, to which it imparts a fine dark-brown color. The French are in the habit of dissolving the sugar, after it has been exposed for some time to a temperature sufficiently high to produce the proper color, in lime-water; this is sold under the name of “coloring.”

CARAT. The term carat is said to be derived from the name of a bean, the produce of a species of erythrina, a native of the district of Shangallas in Africa, a famous gold dust-mart. The tree is called kuara, a word signifying sun in the language of the country, because it bears flowers and fruits of a flame color. As the dry seeds of this pod are always of nearly uniform weight, the savages have used them from time immemorial to weigh gold. The beans were transported into India at an ancient period, and have been long employed there for weighing diamonds. The carat of the civilized world is, however, an imaginary weight, consisting of four nominal grains, a lighter than four grains troy, (poids de marc.) It requires 74 carat grains and 1/56 to equipoise 72 of the other.

It is stated that the carat, a weight used in Mecca, was borrowed from the Greeks, and was equal to the 24th of a demarius or denier.

The Encyclopedists thus explain the carat:—“The weight that expresses the fineness of gold. The whole mass of gold is divided into 24 parts, and as many 24th parts as it contains of pure gold it is called gold of so many carats. Thus, gold of twenty-two parts of pure metal is gold of twenty-two carats. The carat of Great Britain is divided into four grains; among the Germans into 12 parts; and among the French into 32.” Among asayers, even in this country, the German division of the carat is becoming common.

CARBOLIC ACID. (C6H5O.) Syn. Phenic Acid, Phenole, Phenylc Alcohol, Hydrate of Phenyle. The less volatile portion of the fluids produced by distillation of coal tar contain considerable quantities of this substance. It may be extracted by agitation of the coal oils (boiling between 300° and 400°) with an alkaline solution. The latter, separated from the undissolved portion, contains the carbolic acid in the state of carbonate of the alkali. On addition of a mineral acid, the phenole is liberated, and rises to the surface in the form of an oil. To obtain it dry, recourse must be had to digestion with chloride of calcium, followed by a new rectification. If required pure, only that portion must be received which boils at 350°. If, instead of extracting the carbolic acid from coal products boiling between 500° and 400°, a portion be selected distilling between 400° and 428°, and the same treatment as before be adopted, the acid which passes over between 347° and 349° will consist, not of carbolic acid, but of its homologue, cresylc acid, C6H5O7. Commercial carbolic acid is generally very impure. Some specimens do not contain more than 50 per cent. of acids soluble in strong solution of potash. The insoluble portion contains naphthaline, fluid hydrocarbons, and small portions of chinoline and lepine. Carbolic acid, when very pure and dry, is quite solid and colorless. The crystals often remain solid up to 95°, but a trace of water renders them fluid. Its specific gravity is 1.065. Carbolic acid, when mixed with lime and exposed to the air, yields rosolic acid. The lime acquires a rich red color, during the formation of the acid. No means of dyeing reds permanently with this substance have yet been made known. Unfortunately, the red tint appears to require an excess of base to enable it to exist, consequently the carbolic acid of the air destroys the color. (Dr. Angus Smith.) I find that homologues of carbolic acid exist, which boil at a temperature beyond the range of the mercurial thermomter, and that all the acids above carbolic acid afford rosolic acid, or homologues of it, when treated with lime. Creosote of commerce appears to consist of a mixture of carbolic and cresylc acids. If only that portion be received which disills at the temperature given by Reichenbach as the boiling point
of creosote, it will, if prepared from coal oil, consist almost entirely of cresylic acid. (\textbf{Williamson and Fairlie}.) A splinter of deal wood, if dipped first in carboaldehyde, and then in moderately strong nitric acid, acquires a blue tint. For a comparison of the properties of Creosote and Carbolic Acid, see \textit{Creosote}.—C. G. W.

\textbf{CARBON.} \textit{(Equivalent 6; hypothetical density of vapor, 0.8290; combining measure one volume.)} Carbon exists in a considerable variety of forms, most of which are so unlike each other, that it is not surprising the older chemists should have believed them to be compounds. The purest variety of carbon is the diamond. The latter crystallizes in octahedrons and derived forms. The diamond does not owe its hardness and brilliancy solely to its purity, for many specimens of graphite consist of carbon as free from admixture as the best diamonds. The density of graphite and diamond, however, is very different; for while the former seldom exceeds 2.45, and is often much lower, the diamond is very constant, generally ranging between 3.50 and 3.55. Diamonds, if perfectly transparent, leave scarcely any residue when burnt in oxygen gas. If not clear, they yield from 0.05 to 0.20 of ash, consisting chiefly of peroxide of iron, but also containing traces of silice. The refractive power of diamonds is as high as 2.439. Sir Isaac Newton, observing that oily or inflammable bodies generally possessed the greatest refractive powers, inferred from the high index of refraction of the diamond, that it was "an unctuous body congealed." This idea will appear the more happy, when it is considered that the ashes of the diamond exhibit a structure resembling that of vegetable parenchyma. In freedom from ashes, certain graphites nearly approach the diamond, some natural varieties not yielding more than 0.33 per cent.

\textbf{Graphite.}—This kind of carbon is found in many parts of the world, and in different degrees of purity; it is also formed artificially. Some native varieties are exceedingly soft, of a black or grayish tint, metallic lustre, and, in consequence of making a streak on paper, of various degrees of blackness, according to the mode of preparation and other circumstances, are invaluable for the manufacture of artists' pencils. See \textit{Plumbago}.

A very hard graphite is found lining the retorts in which coal gas is made: it is, when cut into plates or rods, used in galvanic arrangements, either for the poles or the insulating elements of batteries.

\textbf{Coke.}—This variety of carbon is produced by the distillation of bit-coal. The largest quantities are produced in the manufacture of coal gas. It of course varies greatly in quality with the coal from which it is procured. The density of coke varies not only with the quality of the coal, but also with the greater or less rapidity of the firing, and the duration of the operation. From 1.2 to 1.4 is not a common range of density in gas-coke tolerably free from ash. I find that a coke of the density 1.323 will have its specific gravity raised to 1.540, if the air in the interstices be removed by placing it in water, under the receiver of the air-pump.

Some varieties of coke, such as those produced in the manufacture of gas from bituminous shales and cannel coals, leave an amnious residue almost equal in bulk to the coke itself.

\textbf{Anthracite} is a very dense natural variety of carbon, its specific gravity varying from 1.390 to 1.7. It differs considerably in quality, some kinds being almost as free from extraneous matters as graphite, while others approach nearer to the nature of coals. Thus, the hydrogen in anthracite oscillates between 1.9 and 4.9. Some varieties of coal have only 4.3 to 5.0 per cent, of hydrogen, thus approximating to those anthracites which have high hydrogens.

\textbf{Charcoal.}—There are several varieties of charcoal: among them may be mentioned those from wood, bones, and the peculiar substance found between the layers of certain pit coals, and known as mineral charcoal. Ordinary charcoal from wood contains many substances besides carbon, among which may be mentioned oxygen, hydrogen, traces of nitrogen, and ashes.

Bone charcoal contains a large quantity of earthy phosphates and carbonates, besides other matters. The mineral charcoal is merely a scientific curiosity. Charcoal is remarkable for its power of absorbing and oxidizing animal and vegetable coloring matters, also for the property it possesses of absorbing gases. The bleaching and disinfecting powers of charcoal appear to depend chiefly on some peculiarity in its structure, enabling it to condense oxygen in a manner somewhat resembling platinum black.

Animal charcoal is used as a bleaching agent in the form of coarse grains: when once used, it may be partially restored to activity by re-burning; but, eventually, it becomes worthless for that purpose, and is then only fit for conversion into superphosphate of lime for manure, by the agency of sulphuric acid. Where acid solutions are to be decolorized by animal charcoal, it is necessary before use to remove the earthy phosphates, &c., by digestion with hydrochloric acid. It is essential that the purified charcoal should be washed with a great quantity of water, in order to remove the acid and the salts formed by its action. Advantage has been taken, by Dr. Steenhouse, of the absorbent power of charcoal, in order to prevent danger arising from putrid or offensive vapors. For this purpose
he has contrived a charcoal respirator, which fulfils its intended office with remarkable success. See CHARCOAL.

For a description of the method of preparing the variety of carbon known as Lamp-Black, see LAMP-BLACK.

The description of the charcoal best adapted for pyrotechnic purposes will be found under the head GUNPOWDER.

Carbon combines with several elements, forming in general well marked and highly important substances. Several of these compounds will be found under the head of CARBONIC ACIDS.

The quantities of charcoal yielded by various kinds of wood have been given by more than one experimenter; but the results are so widely different that no great value can be attached to them. It is evident that the most extreme care would be required in selecting the various woods and preparing them for analysis, if results were desired capable of being employed as standards for reference. Charcoal is extremely indestructible under ordinary circumstances; it is, therefore, usual to char stakes or piles of wood which are to be employed for supporting buildings, or other erections, in damp situations.

It will be seen, from what has already been said, that absolutely pure carbon is scarcely to be met with, even in the diamond. In determining the atomic weight of carbon by combustion of the diamond in oxygen, according to the method employed by MM. Dumas and Stas, it was always necessary to determine and allow for the ashes remaining after the combustion. The purest charcoal that can be obtained by the calculation of sugar for several hours at the highest temperature of a powerful blast furnace, contains oxygen and hydrogen, the former to the extent of about 4/6 per cent., and the latter 92.

Carbon, on uniting with sulphur, forms the curious ferdi volatile fluid known as bisulphide or sulphuret of carbon. In constitution it resembles carbonic acid, and it may, in fact, be considered as that gas in which the oxygen is replaced by sulphur. A new gas has been recently described by M. Baudrimont, bearing the same relation to carbonic oxide that bisulphide of carbon does to carbonic acid: its formula, therefore, is C_{5}S_{7}.

When certain hydrocarbons are treated alternately with chlorine and alkalies, substitution compounds are formed, in which the hydrogen in the original substance is replaced by chlorine; thus olefin gas (C_{4}H_{4}), by this mode of operating, yields C_{4}C_{4}Cl.

It is true that this formula might be written, for simplicity's sake, CCl, but such an expression would be incorrect; because, in the first place, it would not indicate its relation to the parent substance, and in the next, it would not correspond to the, at present, almost universally received axiom, that an equivalent of an organic body is that quantity which is represented by four volumes of vapor.

A bromine of carbon exists; its mode of formation appears to be of a somewhat similar character to the chlorine, for it is sometimes found in commercial bromine, which has been prepared with the agency of other. See BROMINE. It is doubtless formed by the gradual replacement, by bromine, of the hydrogen in the ethylene. — C. G. W.

CARBON, BISULPHIDE OF, formerly Carburet of Sulphur or Sulphuret of Carbon, also called by the elder chemists the Alcohol of Sulphur; a liquid volatile liquid possessing a penetrating foetid smell and an acrid burning taste.

Bisulphide of carbon is prepared by distilling, in a porcelain retort, from pyrites, the bisulphide (bisulphuret) of iron, with a fourth of its weight of well-dried charcoal, both in a state of fine powder, and intimately mixed. The vapor from the retort is conducted to the bottom of a bottle filled with cold water to condense it. The equivalent of the bisulphide of carbon is 38; its formula C_{5}S_{7}.

The bisulphide of carbon is insoluble in water, but it is soluble in alcohol. It dissolves sulphur, phosphorus, and iodine. The solution of phosphorus in this liquid has been employed for electrotyping very delicate objects, such as grasses, flowers, feathers, &c. Any of these are dipped into the solution: by a short exposure in the air, the bisulphide of carbon evaporates, and leaves a film of phosphorus on the surface; they are then dipped into nitrate of silver, by which silver is precipitated in an exceedingly minute film, upon which, by the electrotype process, any thickness of silver, gold, or copper can be deposited. If a few drops of the bisulphide of carbon are put into a solution of the cyanide of silver, from which the metal is being deposited by the electrotyping process, it covers the article quite brightly, whereas, without the bisulphide, the precipitated metal would be dull. See ELECTRO-METALLURGY.

CARBONATES. By this term is understood the salts formed by the union of carbonic acid with bases.

The carbonates are among the most valuable of the salts, whether we regard their physical, geological, chemical, or technical interest. Were limestone and marble the only carbonate familiarly known, they would be sufficient to stamp this class of salts as among the most important. The carbonates of lime, potash, soda, ammonia, and lead are articles of immense importance to the technologist, and are prepared on a vast scale for various purposes in the arts. The carbonates of iron and copper are the most valued ones of those metals. Numerous processes of separation in analysis are founded on the various degrees
of solubility in water and certain reagents of the different carbonates. By taking advantage of this fact, baryta, strontia, and lime may be separated from magnesia and the alcalies. There are few analytical problems which have attracted more attention than the accurate determination of the carbonic acid in the carbonates. This has partly arisen from the frequency with which the potashes, soda ashes, limestone, and other carbonates of commerce, are sent to chemists for analysis. The number of instruments contrived for the purpose is something extraordinary, especially when the simplicity and ease of the operation are considered. Among them all, there is none more convenient or easy to use than that of Par- nell. "It consists of a glass flask (fig. 132) of about two ounces' capacity, fitted with a sound cork, through which two tubes pass, one serving to connect a chloride-of-calcium tube a, while the other, b, will be described presently. A small test-tube, c, is so placed in the flask, and is of such a size, that it cannot fall down, but its contents may be made to flow out by inclining the apparatus to one side. To perform the experiment, a weighed quantity of the carbonate is placed in the flask, and water added up to the level seen in the figure; the test-tube is then filled nearly to the top with concentrated sulphuric acid, and is carefully lowered into the flask; the cork with the tubes attached is then affixed, the aperture b being closed with a small cork. The whole apparatus is now carefully inclined; the flask is then to be inclined so as to allow some of the acid to flow out, and, when the effervescence has subsided, a little more, and so on, until no more carbonic acid is evolved. The flask is now to be so inclined as to cause the whole of the acid to mingle with the aqueous fluid, and thus cause a considerable rise of temperature; this expels the carbonic acid from the liquid; but as an atmosphere of the latter gas fills the flask, it must be removed and replaced by air, as the difference in density of the two is very considerable. For this purpose, the cork b is removed and air is sucked out of d, until it no longer tastes of carbonic acid; the flask is then allowed to become perfectly cold, and, the little cork being replaced, it is then re-weighed; the difference in the two weighings is the amount of carbonic acid in the specimen. On drawing air for some time through the apparatus, it begins slowly to acquire weight, arising from the moisture in the atmosphere being absorbed by the chloride of calcium, and although the error introduced by this means is too minute to affect ordinary experiment, it must not be neglected where, from the quantity of material in the flask being limited, or other causes, a small difference has an important bearing on the result. In this latter case another chloride-of-calcium tube is to be attached to the aperture b, and the air must be drawn through by means of a suction-tube applied at d."—C. G. W.'s Chemical Manipulation.

The commercial value of the carbonates of potash and soda may equally well be determined by ascertaining the quantity of dilute sulphuric acid required to neutralize them.—C. G. W.

CARBUNCLE. A gem much prized by the ancients, and in high repute during the middle ages, from its supposed mysterious power of emitting light in the dark. Benvenuto Cellini affirms, in his treatise on jewellery, that he had seen the carbuncle glowing like a coal with its own light.

"The garnet was, in part, the carbunculus of the ancients, a term probably also applied to the spind and oriental ruby. The Alabandic carbuncles of Pliny were so called because cut and polished at Albania. Hence the name Almandine now in use. Pliny describes vessels of the capacity of a pint formed from carbuncles, 'non claros ac plerumque sordidos ac semper fulgoris horridis,' devoid of lustre and beauty of color,—which probably were large common garnet.—Dana.

CARBURITTED HYDROGEN, or HYDROCARBON. A term used to denote those bodies which consist of carbon and hydrogen only. The number of hydrocarbons now known is very great, and the list is increasing every day. They were very little understood until lately, but so much has now been done that the anomalies and difficulties attending their history are rapidly disappearing. Although the number of individual bodies is, as has been said, very considerable, they are derived from a few great families. The principal are the following:—

Homologues of Olefant gas.

" Methylc.
" Marsh gas.
" Benzole.
" Naphthaline.

Isomers of Turpentine.
The other families which yield hydrocarbon derivatives are less important than the above, and will not be noticed here.

It is curious that the destructive distillation of organic matters is, of all operations, the most fruitful source of these bodies. Coal yields a great number, the nature varying with the temperature. When ordinary coals are distilled at very high temperatures, as in the production of gas, hydrocarbons belonging to the first four families are produced, and also a considerable quantity of naphthaline; but when, on the other hand, they are distilled at as low a heat as is compatible with their thorough decomposition, they yield fluid hydrocarbons, principally belonging to the first two classes, accompanied, however, by a considerable quantity of paraffine. The homologues of olefiant gas have acquired extreme interest, owing to the brilliant results obtained by MM. Berthelot, and de Laca, by Cahours, and Hofmann in the study of their derivatives. The homologues of methyle have attracted considerable attention, in consequence of the successful isolation, by MM. Frankland and Kolbe, of the singular group of hydrocarbons known as the organic radicals, and which, until then, were regarded as hypothetical bodies, existing only in combination.

The hydrocarbon homologues with benzole not only exist in considerable quantity in ordinary coal naphtha, but are produced in a great variety of interesting reactions. Those at present known are contained in the following Table:

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>Boiling Point</th>
<th>Specific Gravity</th>
<th>Specific Gravity of Vapor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzole</td>
<td>C₆H₆</td>
<td>176°C</td>
<td>0.850</td>
<td>Experiment, 2.72</td>
</tr>
<tr>
<td>Toluole</td>
<td>C₆H₅CH</td>
<td>230°C</td>
<td>0.870</td>
<td>Theory, 2.609</td>
</tr>
<tr>
<td>Xylole</td>
<td>C₆H₅CH₂</td>
<td>259°C</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cumole</td>
<td>C₆H₅CH₃</td>
<td>298°C</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cymole</td>
<td>C₆H₅C</td>
<td>327°C</td>
<td>0.861</td>
<td></td>
</tr>
</tbody>
</table>

Benzole has already been sufficiently described, and will not, therefore, be further alluded to. All these hydrocarbons yield a great number of derivatives, when treated with various reagents. By first treating them with strong nitric acid, so as to obtain nitro-compounds, that is to say, the original substance in which an equivalent of hydrogen is replaced by hyponitric acid (NO₃), strongly odorous oils are produced. When treated with sulphide of ammonium or protacetate of iron, these oils become reduced, and yield a very interesting series of volatile organic bases or alkaloids; these are aniline, toluidine, xylidine, cumidine, and cymidine. Mr. Barlow has shown that special precautions are necessary in converting cymole into nitro-cymole, preparatory to the formation of the alkaloid cymidine. Cymole is acted on too violently by nitric acid to allow of the nitro-compound being formed, unless the precaution is taken of cooling the acid and hydrocarbon, by means of a freezing mixture, before allowing them to react on each other. The nitro-compound when well formed, may be reduced in the ordinary manner. These alkaloids have lately acquired special importance in consequence of the valuable dyes that Mr. Perkins has succeeded in producing from them.

Paraffine is a solid hydrocarbon of great interest; it is found both in wood and coal tar. When coal is distilled for the purpose of producing gas, the temperature is so high as to be unfavorable for its production, and consequently mere traces only are found in ordinary coal tar. But if any kind of coal be distilled at the lowest possible temperature, without the resulting naphtha of much lower density than that produced in the ordinary manner, but considerable quantities of paraffine are found in the distillate. The last-mentioned substance is every day becoming more important, in consequence of the valuable illuminating properties that have been found to belong to it. Colorless, inodorous, hard at all moderate temperatures, it forms the most elegant material for candles yet discovered. See Paraffine.

Modern researches have shown that the hydrocarbons generally are formed on one type, viz., hydrogen. Assuming hydrogen in the free state to be a double molecule, H₂, the hydrocarbons are formed by the substitution of one or two equivalents of a positive or negative radical for one or two of the equivalents of hydrogen; thus methyle, the formula of which (for four volumes) is $\text{C}_2\text{H}_2^-$, is hydrogen in which both equivalents are reflected by methyle. Olefiant gas is hydrogen in which one equivalent is replaced by the negative radical acetyle, or vinyl, and so on.

There is one large class of hydrocarbons the rational formula for which are not known, and which will probably remain in this condition for some time. We allude to the numerous essential oils isomeric with oil of turpentine. Many of these have almost
CARMINE.

the same boiling point and precisely the same vapor density as their type; but in odor, fluidity, density in the liquid state, and various other minor points, are essentially different. The following Table exhibits some of their physical properties:

<table>
<thead>
<tr>
<th>Name of Oil</th>
<th>Formula</th>
<th>Rolling Point</th>
<th>Specific Gravity</th>
<th>Specific Gravity of Vapor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil of turpentine</td>
<td>C(^9)(^1)(^8)</td>
<td>328°</td>
<td>0.864</td>
<td>4.704</td>
</tr>
<tr>
<td>attamanta</td>
<td>C(^9)(^1)(^8)</td>
<td>325°</td>
<td>0.843</td>
<td>4.706</td>
</tr>
<tr>
<td>bergamot</td>
<td>C(^9)(^1)(^8)</td>
<td>361°</td>
<td>0.869</td>
<td>4.706</td>
</tr>
<tr>
<td>* Birch tar</td>
<td>C(^9)(^1)(^8)</td>
<td>311°</td>
<td>0.847</td>
<td>5.282</td>
</tr>
<tr>
<td>Cauchoine</td>
<td>C(^9)(^1)(^8)</td>
<td>338°</td>
<td>0.842</td>
<td>4.406</td>
</tr>
<tr>
<td>Oil of caroula, or carucne</td>
<td>C(^9)(^1)(^8)</td>
<td>344°</td>
<td>0.862</td>
<td>4.672</td>
</tr>
<tr>
<td>lemon</td>
<td>C(^9)(^1)(^8)</td>
<td>471°</td>
<td>0.878</td>
<td>6.073</td>
</tr>
<tr>
<td>copaiba</td>
<td>C(^9)(^1)(^8)</td>
<td>490°</td>
<td>0.929</td>
<td>6.073</td>
</tr>
<tr>
<td>cubebis</td>
<td>C(^9)(^1)(^8)</td>
<td>444°</td>
<td>0.849</td>
<td>6.073</td>
</tr>
<tr>
<td>elenin</td>
<td>C(^9)(^1)(^8)</td>
<td>343°</td>
<td>0.849</td>
<td>6.073</td>
</tr>
<tr>
<td>juniper</td>
<td>C(^9)(^1)(^8)</td>
<td>320°</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Terebrie oil accompanying oil of gaultheria</td>
<td>C(^9)(^1)(^8)</td>
<td>320°</td>
<td>-</td>
<td>4.92</td>
</tr>
<tr>
<td>Terebrie oil in clove oil</td>
<td>C(^9)(^1)(^8)</td>
<td>432°</td>
<td>0.901</td>
<td>4.73</td>
</tr>
<tr>
<td>&quot; pepper</td>
<td>C(^9)(^1)(^8)</td>
<td>320°</td>
<td>0.864</td>
<td>4.73</td>
</tr>
<tr>
<td>&quot; balsam of tolu</td>
<td>C(^9)(^1)(^8)</td>
<td>320°</td>
<td>0.837</td>
<td>4.73</td>
</tr>
<tr>
<td>&quot; oil of valerian</td>
<td>C(^9)(^1)(^8)</td>
<td>320°</td>
<td>-</td>
<td>4.60</td>
</tr>
</tbody>
</table>

An inspection of the above Table will show that while, beyond doubt, a great number of essential oils are truly isomeric with turpentine, there are some the constitution of which is by no means well established. The oil of birch tar (used for preparing Russian leather) and cauchoine are by no means sufficiently investigated. The latter is being studied afresh by the author of this article.

The above account of some of the more prominent hydrocarbons is necessarily brief and imperfect; partly because the limits of this work preclude the possibility of entering minutely into the details of their history, and partly because many of them are described at greater length in other articles, especially under SAPIUM.—C. G. W.

CARMINE. (Carminia, Fr.; Karminstoff, Germ.) The coloring matter of the cochineal insect. See COCHINEAL.

There are several methods of preparing carmine, the following being the most approved:

Dr. Pereira speaks highly of this process. A decoction of the black cochineal is made in water; the residue, called carmine grounds, is used by paper-makers. To the decoction is added a precipitant, usually bichloride of tin. The decoction to which the bichloride of tin has been added is put into a shallow vessel and allowed to rest. Slowly a deposit takes place, which adheres to the sides of the vessel, and the liquid being poured off, it is dried: this precipitate is carmine. The liquid, when concentrated, is called liquid rouge.

Carmine is, according to Pelletier and Caventou, a triple compound of the coloring substance and an animal matter contained in cochineal, combined with an acid added to effect the precipitation. The most successful investigator into the coloring matter of the cochineal has been Mr. Warren de la Rue. This chemist had the opportunity of submitting the living insect to microscopical examination. He found it to be covered with a white dust, which was likewise observed on the adjacent parts of the cactus leaves on which the animal feeds. This dust, which he considered to be the excrement of the animal, has, under the microscope, the appearance of white curved cylinders of a very uniform diameter. On removing the powder with ether, and piercing the side of the insect, a purplish-red fluid exudes, which contains red coloring matter, in minute granules assembled round a colorless nucleus. These groups seem to float in a colorless fluid, which appears to prove, that whatever may be the function of the coloring matter, it has a distinct and marked form, and does not pervade, as a mere tint, the fluid portion of the insect. To this coloring matter, Mr. De la Rue has given the name of Carmine Acid, which see.

There are some remarkable peculiarities about the production of carmine: the shade and character of the color are altered by slight, very slight, differences of the temperature at which it is prepared; and with every variation in the circumstances of illumination, a change is discovered in the color. Sir H. Davy relates the following anecdote in illustration of this:
CARNELIAN.

"A manufacturer of carmine, who was aware of the superiority of the French color, went to Lyons for the purpose of improving his process, and bargained with a celebrated manufacturer in that city for the acquisition of his secret, for which he was to pay £1,000. He saw all the process, and a beautiful color was produced, but he found not the least difference in the French method and that which had been adopted by himself. He appealed to his instructor, and insisted that he must have kept something concealed. The man assured him that he had not, and invited him to inspect the process a second time. He very minutely examined the water and the materials, which were in every respect similar to his own, and then, very much surprised, he said:—'I have lost both my money and my labor; for the air of England does not admit of our making good carmine.'

'Stay,' said the Frenchman, 'don’t despise yourself; what kind of weather is it now?'

'A bright sunny day,' replied the Englishman. 'And such are the days,' replied the Frenchman, 'upon which I make my colors; were I to attempt to manufacture it on a dark and cloudy day, my results would be the same as yours. Let me advise you to make your carmine on sunny days.'"

Experiments on this subject have proved that colored precipitates which are brilliant and beautiful when they are precipitated in bright sunshine, are dull, and suffer in their general character, if precipitated in an obscure apartment, or in the dark.

CARMINIC ACID. The following is the best method of obtaining, in a state of purity, the coloring principle of cochineal, or carminic acid: The ground cochineal is boiled for about twenty minutes with fifty times its weight of water; the strained decoction, after being allowed to subside for a quarter of an hour, is decanted off and precipitated with a solution of the acetate of protoxide of lead, acidulated with acetic acid, (1 acid to 6 of the salt.) The washed precipitate is decomposed by hydrosulphuric acid, (sulphuretted hydrogen,) the coloring matter precipitated a second time with acidulated acetate of protoxide of lead, and decomposed as before. The solution of carminic acid thus obtained, is evaporated to dryness, dissolved in boiling absolute alcohol, dissolved with a portion of carminate of protoxide of lead, which has been reserved, (for the separation of the phosphoric acid,) and then mixed with ether, to precipitate a small portion of nitrogenous matter. This filtrate yields, upon evaporation in vacuo, pure carminic acid. When thus prepared, it is a purple-brown friable mass, transparent when viewed by the microscope, and pulverizable to a fine red powder, soluble in water and in alcohol in all proportions, and very slightly soluble in ether, which does not however precipitate it from its alcoholic solution. It decomposes at temperatures above 136°. The aqueous solution has a feebly acid reaction, and does not absorb oxygen from the air; alkalies change its color to purple; in the alcoholic tincture, they produce purple precipitates; the alkaline earths also produce purple precipitates. Alum gives with the acid a beautiful crimson lake, but only upon the addition of a little ammonia. The acetates of the protoxides of lead, copper, zinc, and silver give purple precipitates; the latter is immediately decomposed and silver deposited. Protochloride and bichloride of tin give no precipitates, but change the color to a deep crimson.

The analyses of carminic acid led to the formula C₈H₇P₀₉. The compound of protoxide of copper appeared to be the only salt that could be employed with any certainty for the determination of the atomic weight, as the other salts furnished no satisfactory results. The salt of copper was prepared by adding cautiously to an aqueous solution of carminic acid, acidulated with acetic acid, acetate of protoxide of copper, so as to leave an excess of carminic acid in the liquid. When dried it is a brown-colored hard mass.

—Liebig and Kopp's Report.

CARNELIAN, or CARNELIAN. (Cornellina, Fr.; Kornel, Ger.; Cornalina, Ital.) A reddish variety of chalcedony, generally of a clear bright tint; it is sometimes of a yellow or brown color, and it passes into common chalcedony through a grayish red. Herrnitz, by his analyses, shows that the color is due to oxide of iron. He found

<table>
<thead>
<tr>
<th>Per Cent.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Peroxide of iron</td>
<td>0°150</td>
</tr>
<tr>
<td>Alumina</td>
<td>0°81</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0°28</td>
</tr>
<tr>
<td>Potash</td>
<td>0°0483</td>
</tr>
<tr>
<td>Soda</td>
<td>0°75</td>
</tr>
</tbody>
</table>

the remainder being Silica.—Dana.

Carnelians are the stones usually employed when engraved for seals. The French give to those carnelians which have the utmost transparency and purity, the name of Cornaline d'australe roche. See AGATE.

The late James Forbes, Esq., long a resident in India, and with ample means of reference to the province of Guzerat, thus describes the locality of the carnelian mines:—

"Carnelians, agates, and the beautifully variegated stones improperly called Moeha Stones, form a valuable part of the trade at Cambay. The best agates and carnelians are found in peculiar strata, thirty feet under the surface of the earth, in a small tract
among the Rajepippee hills on the banks of the Nerbbudda; they are not to be met with in any other part of Guzerat, and are generally cut and polished in Cambay. On being taken from their native bed, they are exposed to the heat of the sun for two years: the longer they remain in that situation, the brighter and deeper will be the color of the stone. Fire is sometimes substituted for the solar ray, but with less effect, as the stones frequently crack, and seldom acquire a brilliant luster. After having undergone this process, they are boiled for two days, and sent to the manufacturers at Cambay. The agates are of different hues; those generally called carnelians are dark, white, and red, in shades from the palest yellow to the deepest scarlet.

The variegated stones with landscapes, trees, and water beautifully delineated, are found at Copper-wrange, or, more properly, Cubbee-prung. 'The Five Tombs,' a place sixty miles distant."—Oriental Memoirs, vol. i. p. 323, 2d ed.

At Neeomandra, a village of the Rajepippee district, and three miles east, are some celebrated carnelian mines. The country in the immediate vicinity of the mines is but little cultivated; and on account of the jungles, and their inhabitants the tigers, no human inhabitants are found nearer than Battampoor, which is seven miles off. The miners have huts at this place when stones are burned.

The carnelian mines are situated in the wildest parts of the jungle, and consist of numerous shafts worked down perpendicularly about 4 feet wide, the deepest about 50 feet. Some extend at the bottom in a horizontal direction, but usually not far, the nature of these pits being such as to prevent their being worked a second year, on account of the heavy rains causing the sides to fall in; so that new ones must be opened at the conclusion of every rainy season. The soil is gravelly, and consists chiefly of quartz sand, reddened with iron and a little clay. The nodules weigh from a few ounces to even two or three pounds, and lie close to each other, but for the most part distinct, not being in strata, but scattered through the masses in great abundance.

On the spot, the carnelians are mostly of a blackish-olive color, like common dark flints, others somewhat lighter, others still lighter with a milky tinge; but it is quite uncertain what appearance they will assume after they have undergone the process of burning.

From Neeomandra they are carried by the merchants to Cambay, where they are cut, polished, and formed into beautiful ornaments, for which that city is so justly celebrated.

The stones from Cambay, are offered in commerce, cut and uncut, as roundish pebbles from 1 to 3 inches in diameter. The color of red carnelian of Cambay varies from the palest flesh-color to the deepest blood-red; the latter being most in demand for seals and trinkets. The white are scarce, but when large and uniform they are valuable; the yellow and variegated are of little estimation in the Bombay market.

The following is a statement of the carnelians exported by sea from the port of Bombay to foreign and Indian stations not subject to the Presidency of Bombay, from 1st May, 1856, to 30th April, 1857:

<table>
<thead>
<tr>
<th>Station</th>
<th>Carnelians Exported (in rupees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>African Coast</td>
<td>20,583</td>
</tr>
<tr>
<td>Arabian Gulf</td>
<td>26,187</td>
</tr>
<tr>
<td>Ceylon</td>
<td>2,192</td>
</tr>
<tr>
<td>China, Hong Kong</td>
<td>916</td>
</tr>
<tr>
<td>Penang, Singapore, and Straits of Malacca</td>
<td>8,655</td>
</tr>
<tr>
<td>Persian Gulf</td>
<td>7,777</td>
</tr>
<tr>
<td>Suez</td>
<td>4,755</td>
</tr>
<tr>
<td>East Indian ports of Malabar</td>
<td>400</td>
</tr>
</tbody>
</table>

Total value in rupees, 68,046; the rupee being valued at two shillings.

CARRAGEEN. (Chondrus crispus.) Irish Moss. See Algae.

CARRAGEENIN. The mucilaginous constituent of carrageen moss. It is called by some writers "vegetable jelly" or "vegetable mucilage," by others "pectin." "It appears to me (Verree) to be a particular modification of mucilage, and I shall therefore call it carrageen. It is soluble in boiling water, and its solution forms a precipitate with nitrate of lead, and silicate of potash, and, if sufficiently concentrated, gelatinizes, on cooling. Carrageen is distinguished from ordinary gum by its aqueous solution not producing a precipitate on the addition of alcohol, from starch by its not assuming a blue color with tincture of iodine; from animal jelly, by tincture of magueys causing no precipitate; from pectin, by acetate of lead not throwing down any thing, as well as by no mucic acid being formed by the action of nitric acid." The composition of carrageenin dried at 212° F., according to Schmidt, is represented by the formula C₁₀H₂₀O₁₀, so that it appears to be identical with starch and sugar. Mulder, however, represents it by the formula C₁₀H₁₃O₈.

CARTHAMUS, or SAFFLOWER. The coloring matter of safflower has been examined by Salviat, who has found much difference in carthamus of reputed good quality; a few of his results will suffice:—
Salvétat has found it advantageous to mix the red of safflower with the pigments used in porcelain painting for purple, carmine, and violet, colors which, in consequence of the difference of their shade before and after firing, are very liable to mislead. To avoid this, he imparts to the pigment, (consisting of flux, gold, purple, and chloride of silver,) by means of the red of carthamus suspended in water, the same shade which he desires to obtain after firing.

CARVING BY MACHINERY is an art of comparatively modern date, nearly, if not the whole of the originators and improvers of it, being men of the present day. It is true that the Medallion Lathe and many other appliances for ornamental turning and drilling can claim a much earlier origin, but these can scarcely be called carving machines, and are altogether incapable of aiding the economy of producing architectural decorations of any kind. We are not aware of any practical scheme for accomplishing this object prior to the patent of Mr. Joseph Gibbs, in 1829, which we believe was used by Mr. Nash in ornamenting some of the floors of Buckingham Palace, and on many other works of inlaying and tracery. The cutting of ornamental forms in low relief seems to have been the principal object of the inventor; and this he accomplished satisfactorily by a series of ingenious mechanical arrangements, which greatly reduced the cost, while securing unusual accuracy in this kind of work. Some modifications of machinery for copying busts, bosses, and other works in bold relief are also described in Mr. Gibbs’s patents, but these were never carried into successful practice. The tracery and inlaying machine is illustrated by Fig. 153, which is a plan of the machine. A is a shaft capable of vertical motion in its bearings, which are in the fixed framing of the machine; n, c, and v, e, are swing frames jointed together by a
short vertical shaft $\alpha$, and securely keyed to the shaft $\lambda$. The point $b$ is the axis of a revolving tool, which is driven by the belts $c$, $d$, $e$, and the compound pulleys $f$, $g$, $h$, which increase the speed at each step; $r$, $a$, $n$, is the table on which the work is fixed; $l$, $k$, the work; and $k$, $l$, a temper of brass pierced with the horizontal form of the pattern to be produced in the wood; this temper is securely fixed on the top of the work, or over it, and the machine is adjusted for action.

There is a treadle, not shown in the figure, which enables the workman to lift or depress the shaft $\lambda$, and the swing frames and tool attached to it; he can thus command the vertical position of the tool with his foot, and its horizontal position with his hand by the handwheels $m$, $n$, which turn freely on a collar of the swing frame surrounding the mandril or tool-holder. The tool, having been brought over one of the apertures of the temper when in rapid action, is allowed to sink to a proper depth in the wood underneath, and the smooth part of its shaft is then kept in contact with the guiding edges of the temper and passed round and over the entire surface of the figure, until a recess of the exact size and form of that opening in the temper is produced; this process is repeated for every other opening, and thus a series of recesses are formed in the oak flooring planks which correspond with the design of the templets used. To complete the work, it is requisite to cut out of some darker or differently colored material a number of thin pieces which will fit these recesses, and these are produced in the same way from templets which will fit the various apertures of that first used; these pieces are next glued into the recesses, and the surface when planed and polished exhibits the pattern in the various colors used. For inlaying it is important that the cutting edge of the tool should travel in the same radius as the cylindrical shaft, which is kept against the edge of the temper; but if the tool is a moulded one, a counterpart of its mouldings will be produced in the work, while the pattern, in planes parallel to that of the panel, will have the form of the apertures in the temper used. In this way, by great care in the preparation of the templets and the tools, much of the gothic tracery used in church architecture may be produced, but the process is more applicable to stone than to wood when moulded tools are requisite.

Mr. Irving's patents for cutting ornamental forms in wood and stone are identical in principles of action and in all important points of construction with the arrangements previously described. In that of 1843 he particularly claims all combinations for accomplishing the purpose, "provided the swing frame which carries the cutter, and also the table on which the article to be wrought is placed, have both the means of circular motion." The pierced stone is fixed in the head of the power, and the work and temper are fixed on a circular iron table, which is at liberty to revolve on its axis. The swing frame which carries the cutter is single, as in Mr. Gibbs's curved moulding machine, and its radius so adjusted, that an arc drawn by the tool would pass over the centre of the circular table. The mode of operating with this machine was to keep the shaft of the tool against the guiding edge of the temper, by the joint movements of the table on its centre, and of the swing frame about its shaft; and it will be obvious that by this means any point of the table could be reached by the tool, and therefore any pattern of moulded work within its range produced, in the way already described in speaking of Mr. Gibbs's machinery. But as these modifications of the original idea are not, strictly speaking, carving machines, seeing that they only produced curved mouldings, we need not further describe them.

Perhaps the most perfect carving machine which has been made for strictly artistic works is that used by Mr. Cheverton for obtaining his admirable miniature reductions of life-sized statuary; but we can only judge of the perfection of this machine by its work, seeing that the inventor has more faith in secrecy than patents, and has not made it public.

The carving machinery which is best known, and has been most extensively used, is that invented by Mr. Jordan and patented in 1815, since which date it has been in constant operation in producing the carved decorations of the interior of the Houses of Parliament. Its principle of action and its construction is widely different from that above described, and it is capable of copying any carved design which can be produced, so far as is possible by revolving tools; the smoothness of surface and sharpness of finish are neither possible nor desirable, because a keen edge guided by a practised hand will not only produce a better finish, but it will accomplish this part of the work at less cost; the only object of using machinery is to lessen the cost of production, or to save time; and in approaching towards the finish of a piece of carving, there is a time when further progress of the work on the machine would be more expensive than to finish it by hand. This arises from the necessity of using smaller tools towards the finish of the work to penetrate into its sharp recesses, and the necessarily slow rate at which these cut away the material; it is consequently a matter of commercial calculation, how far it is desirable to finish on the machine, and when to deliver it into the hands of the artist, so as to secure the greatest economy. This depends in a great measure on the hardness of the material; rosewood, ebony, box, ivory, and statuary marble should be wrought very nearly to a finish; but lime, deal, and other soft woods should only be roughly pointed.

Fig. 154 is a plan of the machine, fig. 155 a front elevation, and fig. 156 a side eleva-
CARVING BY MACHINERY.

The same letters indicate the same part in all the figures. The carving machine consists of two distinct parts, each having its own peculiar motions quite independent of the other, but each capable of acting simultaneously and in unison with the other. The first, or horizontal part, is the bed plate "floating-table," &c., on which the pattern and work are fixed; all the motions of this part are horizontal. The second, or vertical part, is that which carries the cutters and tracer, the only motion of which, except the revolution of the tools, is vertical.

The horizontal part consists of three castings: The bed plate A, B, C, D, which is a railway supported on piers from the floor and fixed strictly level. The carrying frame E, F, G, H, mounted on wheels and travelling on the bed plate, (the long sides of this frame are planed into (v) rails) and the "floating-table" I, J, K, L, which is also mounted on wheels to travel on the rails of the carrying frame. It is called the "floating-table," because it can be moved in any horizontal direction with almost as much facility as if it were a floating body. Primarily this table has two straight-lined motions at right angles to each other, but by combination of these it may move over any figure in an horizontal plane; and because this is accomplished without angular motion about a centre, every point in the surface of the table moves through the same figure at the same time; hence the power of producing many copies of a pattern simultaneously.

The second, or vertical part of the machine, is a cast-iron bridge supported on columns across the centre of the bed plate; on the centre of this bridge piece is a wide vertical slide, S, T, with a (r) slotted bar on its lower edge; to this bar the mandril heads or tool-holders, R, T, U, V, are bolted, at such distances apart as suits the width of the work in hand, and in such numbers as it is convenient to work at one time. If the framing of the machine is massive and well fixed, six or eight narrow pieces may be carved at once; but if the width of the work is equal to half that of the table, only one can be done, as in that case half the table is required for the pattern. The motion of the vertical slide is governed by the workman's foot on the treadle R, Q, S; at s balance weights are placed, so as to
CARVING BY MACHINERY.

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DRIVING PULLEY

156
adjust the force with which the tools will descend on the work; any pressure on the foot-board a lifts the slide, and with it the tools and tracing point.

Returning to the horizontal part of the machine, $d, e, f, g$, is the pattern or original carving which is to be copied, and $h, i, j, k$, two copies in progress. The movements of the floating-table are managed by the workman with the hand-wheels $u, v$; the left hand, on $v$, directs the lateral motion on the frame, and the right, on $v$, directs the longitudinal motion on the bed plate; the left-hand movement is communicated by the cord $x, x$, which is fixed to brackets $w, w$, underneath the table, and makes one turn round a small pulley on the axis of the wheel $v$. The right-hand movement is communicated by the cord $z$, which is fastened to each end of the bed plate, and makes one or two turns round the pulley $z$. When at work the man stands inside the frame of the bed plate, with his right foot on the board $n$ and his hands on the steering wheels; on releasing the pressure of the foot, the vertical slide descends by its unbalanced weight until the tracer $h$ comes in contact with the pattern; the cutters $m, m$, are made to revolve by steam power at the rate of seven thousand times per minute, and are so shaped as to cut like a revolving gouge, so that they instantly cut away all the superfluous material they come in contact with; and, by the time the tracer has been brought over every part of the pattern, the pieces $h, i, j, k$ will have become exact copies of it.

So far as panel carving is concerned, the whole machine has been described; but it is requisite to elaborate its construction a little more for the purpose of carving on the round, and copying subjects which require the blocks to be cut into all possible directions. Various modifications have been used, but we shall only explain that which we think best adapted to ornamental carving. It is not requisite that we should go into the various applications of this machine, to the manufacture of printing blocks, ship’s blocks, gunstocks, letter cutting, tool handling, cabinet shaping, &c., &c., of all which have been shown from time to time to be within its power; nor is it requisite to describe more recent inventions founded on it, as they will properly come under other heads.

When the machine is intended to copy any form which can be carved by hand, the floating-table is differently constructed, but all other parts remain as before. In the floating-table used for this purpose, there is an opening in the centre of the table, and a turning plate, which is mounted a few inches above the level of the table, to turn in bearings in standards. Underneath the turning plate, and forming a part of it, there is an arc of rather more than half a circle, having its centre in the axis on which the plate revolves, and is coggled on its edge to fit the threads of the tangent screw on the axis of the wheel, so that by turning this wheel, and dropping its detent into any cog, the workman can fix the plate at any angle with the horizon. There are three chucks fitted into sockets of the turn plate, and these are similarly divided on their edges by holes or cogs, into which detents fall, so as to secure them steadily in any required position.

When in use one chuck carries the pattern, and two other chucks the work. The process of carving is precisely the same as before; but in consequence of the work and pattern being so mounted that it can be turned into every possible position with respect to the cutters, any amount of undercutting which is possible in hand carving is also possible in machine carving.

In going through the process the workman will, of course, attack the work when it is placed in a favorable position for the tools to reach a large portion of its surface; and having completed as much as possible on that face, he will turn all the chucks through the same number of divisions; the pattern and work will still have the same relative position to each other as before, but an entirely new face of both will be presented to the tools; this will be carved in like manner, and then another similar change made, and so on until all has been completed which can be reached without changing the angular position of the turning plate. This can be done by the wheel, and when a sufficient number of these changes have been gone through, the work will be complete on every face, although the block may have required to be pierced through in fifty different directions.—T. B. J.

CASE-HARDENING. When case-hardening is required to terminate at any particular part, as a shoulder, the object is left with a band or projection; the work is allowed to cool without being immersed in water; the band is turned off, and the work, when hardened in the open fire, is only effected as far as the original cemented surface remains. This ingenious method was introduced by Mr. Roberts, of Manchester, who considers the success of the case-hardening process to depend on the gentle application of the heat; and that, by proper management not to overheat the work, it may be made to penetrate three-eighths of an inch in four or five hours.—Holtzapffel.

The recent application of prussiate (ferrocyanate) of potash to this purpose is a very interesting chemical problem. The piece of iron, after being polished, is to be made brightly red-hot, and then rubbed or sprinkled over with the above salt in fine powder, upon the part intended to be hardened. The prussiate being decomposed, and apparently dissipated, the iron is to be quenched in cold-water. If the process has been well managed, the surface of the metal will have become so hard as to resist the file. Others propose to smear
over the surface of the iron with loam made into a thin paste with a strong solution of the prussiate, to dry it slowly, then expose the whole to a nearly white heat, and finally plunge the iron into cold water, when the heat has fallen to dull redness. See STEEL.

CASK. (Tonneau, Fr.; Fass, Germ.) Much ingenuity has been displayed in cutting the curvilinear and bevelled edges of the staves of casks by circular saws. Sir John Robinson proposed many years back that the stave should be bent to its true curve against a curved bed, and that while thus restrained its edges should be cut by two saws s s, placed in radii to the circle, the true direction of the joint as shown by the dotted circle fig. 157, representing the head of the cask.

Mr. Smart cuts the edges of thin staves for small casks on the ordinary saw-bench, by fixing the thin wood by two staples or hooks to a curved block, the lower face of which is bevelled to give the proper chamfer to the edges, fig. 158. One edge having been cut, the stave is released, changed end for end, and refixed against two pins which determine the position for cutting the second edge, and make the staves of one common width. The curved and bevelled block is guided by two pins pp, which enter a straight groove in the bench parallel with the saws. This mode of bending is from various reasons found inapplicable to large staves, and these are cut, as shown in three views, fig. 159, whilst attached to a straight bed, the bottom of which is also bevelled to tilt the stave for chamfering the edge. To give the curve suitable to the edge, the two pins on the under side of the block run in two curved grooves g g in the saw-bench, which cause the staves to sweep past the saw in the arc of a very large circle, instead of in a right line, so that the ends are cut narrower than the middle. Mr. Smart observes (Trans. Soc. of Arts, vol. xlvii) that in staves cut whilst straight, the edges become chamfered at the same angle throughout, which although theoretically wrong is sufficiently near for practice; the error is avoided when the staves are cut whilst bent to their true curvature.

The necessary flexibility which is required for bending the staves of casks is obtained by steaming them in suitable vessels in contact with rigid moulds. By Taylor's patent machinery for making casks, the blocks intended for the staves are cut, out of white Canada oak, to the size of thirty inches by five, and smaller. They are well steamed, and then sliced into pieces one-half or five-eighths of an inch thick, at the rate of 200 a minute, by a process far more rapid and economical than sawing, the instrument being a revolving iron plate, of 12 or 14 feet diameter, with two radical knives arranged somewhat like the irons of an ordinary plane or spokeshave.

CASSAREEP or CASSIREPE. The concentrated juice of the roots of the bitter cassava flavored by aromatics. It is used for flavor soups, and other dishes, and is the basis of the West Indian dish pepper-pot. In French Guiana, the term cabion is applied to a similar condiment.—Pereira.

CASSITERITE. Oxide of Tin; Stream Tin. Stream Tin is the alluvial ḏīvrīs of tin veins. (See Tin Ore.) This is one of the very objectionable names, of which a very great number have, of late years, been introduced into the science of Mineralogy.

CASSIUS, purple powder of. Professor Graham, in his Elements of Chemistry," gives the following account of the purple of cassius, and of its preparation: "When protochloride of tin is added to a dilute solution of gold, a purple powder falls. It is obtained of a finer tint when protochloride of tin is added to a solution of the sesquichloride of iron till the color of the liquid takes a shade of green, and the liquid in that state added, drop by drop, to a solution of sesquichloride of gold free from nitric acid, and very dilute. After 24 hours a brown powder is deposited, which is slightly transparent, and purple-red, by transmitted light; when dried and rubbed to powder, it is of a dull blue color. Heated to redness it loses a little water but no oxygen, and retains its former appearance. If washed with ammonia, on the filter, while still moist, it dissolves, and a purple liquid passes, which rivales the hypermanganate of potash in beauty. . . . It may also be formed by fusing together 2 parts of gold, 3/2 parts of tin, and 15 parts of silver, under borax, to prevent the oxidation of the tin; and treating the alloy with nitric acid, to dissolve out the silver; a purple residue is left, containing the tin and gold that were employed."
CEedar.

"Berzelius proposed the theory that the powder of Cassius may contain the true protoxide of gold combined with sesquioxide of tin, AuOSnO₂, a kind of combination containing an association of three atoms of metal, which is exemplified in black oxide of iron, spinel, Frankhinite, and other minerals. . . . A glance at its formula shows how readily the powder of Cassius, as thus represented, may pass into gold and binoxide of tin, AuOSnO₂ = Au₂SnO₃"—Graham and Watts.

CASTORINE. A substance existing in castoreum. Its chemical formula is not known, and its entire history requires to be freshly investigated. It is obtained by treating the secretion of the castors with hot alcohol, and filtering through a Platanour's ebullition funnel. On cooling, the alcohol deposits crystals of a fatty substance. The castorine is retained in the mother liquor, and is procured by evaporation on the water-bath to a small bulk, and then setting aside to allow crystals to form. Castorine crystalizes in needles possessing a slight odor of castoreum.—C. G. W.

CASTOR OIL. The expressed oil of the seeds of the Palma Christi or Ricinus communis, a native tree of the West Indies and South America; but which has been cultivated in France, Italy, and Spain.

In England the castor oil is expressed from the seeds by means of powerful hydraulic presses fixed in rooms artificially heated. It is purified by repose, decantation, and filtration, being bleached in pale-colored Winchester quart bottles which are exposed to light on the tops of houses. Unbleached castor oil is certainly more acrid and possesses more purgative properties than such as has been long exposed to the light; we may therefore infer that the acrid residu of the oil has undergone some chemical change. In America the oil is expressed from the seeds by pressure between heated plates. In the East Indies, women shell the fruit; the seeds are placed between rollers and crushed; they are then put into hemp cloths, and pressed in the hydraulic press. The oil thus procured is afterwards heated with water in a tin boiler, until the water boils, by which the mucilage or albumen is separated as a scum. The East Indian castor oil is sold in England as cold drawn. The following is the composition of castor oil:—

<table>
<thead>
<tr>
<th>Urea</th>
<th>Saussure</th>
<th>Carbon</th>
<th>Hydrogen</th>
<th>Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>74/00</td>
<td>74/178</td>
<td>10/29</td>
<td>10/034</td>
<td>14/71</td>
</tr>
<tr>
<td>100/000</td>
<td>100/000</td>
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</table>

CATALYSIS. A term introduced to denote the very peculiar phenomenon of one body establishing, by its mere presence, a like condition in another body to that which exists in itself. Thus a piece of meat undergoing the putrefactive fermentation, almost immediately, sets up a similar action in fresh meat, or produces in a suberinaceous fluid that motion which is known as vicarious fermentation. The action of the yeast plant,—a living organization,—establishes an action throughout a large quantity of an infusion of malt,—fermentation, or that disturbance which leads to the conversion of sugar into alcohol. This catalytic power is ill understood, and we are content to hide the imperfection of our knowledge under a sounding name.

CATECHINE. Catechins Acid. When Gambir catechu is treated with water, an insoluble residue left, which has been termed by Nees resinus lamin. Its composition is C₇H₈O₆.

CATS EYE. A translucent quartz, presenting peculiar internal reflections. This effect is said to be owing to filaments of asbestos. When cut en cabochon, it is esteemed as an ornamental stone.

CEDAR. (Cedre, Fr.; Cedar, Germ.) The cedar of Lebanon, or great cedar, (Pinus cedrus,) is a cone-bearing tree. This tree has been famous since the days of Solomon, who used it in the construction of the temple. The wood has been obtained from Crete and Africa.

Specimens have also been procured from Morocco, showing the probability that the range of the tree not only extends over the whole group of mountains which is situate between Damascus and Tripoli in Syria, and which includes the Lebanon and Mounts Ama
dus and Taurus of antiquity, and various others,—but that its distribution on the mountainous regions of North Africa is extensive.

Indeed, if we are to suppose that the cedar and the cedar wood mentioned by many of the ancient writers referred exclusively to the Lebanon species, we must believe that its distribution at one period extended over countries where no trace of its having existed now remains. Egypt, Crete and Cyprus are mentioned by Pliny and Theophrastus as native habitats of the cedrus; we may thus fairly infer that the cedrus of the ancients as frequently had reference to the other confere as to the Lebanon species.

The pencil cedar is the Juniperus Virginiana. It is imported from America in pieces from 6 to 10 inches square. The grain of the wood is remarkably regular and soft, on which account principally it is used for the manufacture of pencils, and from its agreeable scent for the inside of small cabinets; it is also made into matchs for the drawing room.
CEDIRET.

The general use of the cedar wood dates from the highest antiquity. Pliny makes mention of cedar wood and the uses to which it was applied, and cites, as examples of its durability and imperishable nature, the timber of a temple of Apollo at Utica, in Africa, which, when nearly 2,000 years old, was found to be perfectly sound,—and the famous statue of Diana in the temple of Saguntum in Spain. Cedria, an oil or resin extracted from a cedar, was also, according to Vitruvius, used to smear over the leaves of the papyrus to prevent the attacks of worms; and Pliny states that the Egyptians applied it with other drugs in the preparation of their mummies; but whether this extract was obtained from the Lebanon cedar or from trees belonging to the genus Cupressus or Juniperus, which also afford odoriferous resins, it is now impossible to ascertain.

In regard to the cedar and cedar wood mentioned in profane history, it is difficult, from what we have already stated, to determine what has reference to the true cedar, and what belongs to other coniferous species; all that we can know for certainty is that a wood called cedar, distinguished for its incorruptible nature, was frequently used for purposes most important in the eyes of the pagan, viz., in the building and decoration of their temples, and for the statues or images of their heroes and gods.

The peculiar balsamic odor of cedar has long been held as a means to preserve articles from the attacks of insects; chips and shavings of the wood have been in this way kept in collections of linen, papers, and objects of preservation. Cabinets have been recommended, or at least the drawers and fittings, to be made of cedar. That the popular character may receive its due limitation, it may be useful to call attention to some facts when cedar is employed as a means of preservation.

That the odoriferous substance when diffused may affect some forms of organic life, is not disputed, but it is as probable some of the effect may be due to covering the insect with a coating of varnish, alike irritating and interfering with the texture of the surfaces of the body; but the rule cannot be general; if the creatures have a sufficient hardihood they may, and indeed do, attack the wood itself.

The following cases will show that the substances emanating from cedar may produce unexpected interference. Mr. Vuillamy states that George III. had a cabinet in the observatory at Kew with drawers of cedar wood in them; watches were placed with the intention of keeping them going. In a short time they all came to rest; the experiment, however, repeated, had the same result: on examination, the oil used in different parts of the watches was found to be completely changed into a substance like gum. Mr. Farey's observations, also communicated to the Institution of Civil Engineers, still more show the extraordinary atmosphere produced in close cabinets of cedar wood, and of the effects upon delicate objects. The late Mr. Smith, of Derby, having shown him a small collection of minerals which had been locked up in closely fitted drawers of cedar wood; on opening the drawers for the first time after some months, the minerals were found to be covered with a gummy matter having the strong odor of cedar, and troublesome to remove; the bright surface of the crystals appeared as if varnished in an unskilful manner. The cedar had given off a vapor that had condensed on all the minerals, and the same effect might be expected to be produced upon watches, metals, and other substances.

Indeed, cases are known where the action of cedar has produced unpleasant effects, and not without exciting the idea of remote danger. A bundle or package of black lead pencils, the wood as usual of cedar, had been kept in stock upon a shelf, wrapped in paper; by the heat of the gas, &c., the cedar vapor had attacked the paper and its materials; the paper seemed thick and stiffened as with varnish, forming one mass with the pencils, and damaging the paper and articles of stock near, while the paper was rendered highly inflammable, burning with a great flame. This case was laid before the officers of the Society of Arts, who are desirous of extending the proper uses of cedar wood, and of avoiding the evils arising from unsuspected chemical action.—T. J. P.

CEDIRET. A singular compound of unknown composition existing in wood-tar. When crude cresote is dissolved in potash and acetic acid is added, cresote separates. If the cresote be decanted and the solution of acetate of potash be distilled, a fluid is obtained at a certain epoch of the distillation, which, when dropped into persulphate of iron, forms a network of crystals. This is cediret. It has not yet been observed in coal naphtha.

CELESTINE. (Strontianum sulphatic, Fr.; Celestria, Germ.) Celestine is usually associated with secondary or Silurian limestone or sandstone, also with trap-rocks; and it is found in the red marl formations associated with gypsum. In Sicily it is commonly associated with sulphur. The celestine of Girgenti was found by Stromeyer to be composed as follows:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphuric acid</td>
<td>42.08</td>
</tr>
<tr>
<td>Strontian</td>
<td>56.25</td>
</tr>
<tr>
<td>Red oxide of iron</td>
<td>0.03</td>
</tr>
<tr>
<td>Carbonate of lime</td>
<td>0.09</td>
</tr>
<tr>
<td>Water</td>
<td>0.18</td>
</tr>
</tbody>
</table>
CHARCOAL

This mineral is found in Sicily, at Bey in Switzerland and Corrili in Spain. It exists at Aust Ferry near Bristol, in trap-rocks near Tantellau in the East Lothians, and at Calton Hill, Edinburgh. Dana gives several localities for celestine in America. It is decomposed by ignition with charcoal into sulphide of strontia, which is converted into the nitrate by the action of nitric acid.

CEMENTS. (Clayenta, Fr.; Cimenta, Kite, Germ.) Substances which are capable of assuming the liquid form and of being applied between the surfaces of bodies so as to unite them firmly when solidifying. They are of very varied character.

Gum, glue, and paste are cements, the uses of which are well known.

Sir John Robinson's cement he thus describes:

"If it be wished to dissolve good isinglass in spirits of wine, it should first be allowed to work for some time in cold water, when swelled it is to be put into the spirit, and the bottle containing it being set in a pan of cold water may be brought to the boiling point, when the isinglass will melt into a uniform jelly, without lumps or strings, which is apt to have if not swelled in cold water previously to being put into spirits. A small addition of any essential oil diminishes its tendency to become mouldy.

If gelatine, which has been swelled in cold water, be immersed in linseed oil and heated, it dissolves, and forms a glue of remarkable tenacity, which, when once dry, perfectly resists damp, and two pieces of wood joined by it will separate anywhere else rather than at the joint. Ordinary glue may be thus dissolved, and sometimes a small quantity of red lead in powder is added."

Lapidaries' cement is made of resin, tempered with beeswax and a little tallow, and hardened with chrome or Spanish brown and whiting.

Opticians' cement, for fixing glasses for grinding, is made by sifted wood ashes with meltedpitch, the essential oil of which is absorbed by the wood ashes, and the adhesiveness of the pitch is therefore reduced. The proportions are somewhat dependent on the temperature of the weather and the qualities of the pitch; but generally about 4 lbs. of wood ashes to 14 lbs. of pitch are employed, and the cement, if too hard and brittle, is softened with hog's lard and tallow.

Japanese cement is said to be prepared by mixing rice flour intimately with cold water, and then boiling the mixture; it is white, and dries nearly transparent. See Mortar.

CEYLON MOSS. (Plocaria candida.) See Algae.

CHALLIS. About the year 1832 this article was introduced, certainly the neatest, best, and most elegant silk and worsted article ever manufactured. It was made on a similar principle to the Norwich crepe, only thinner and softer, composed of much finer materials; and instead of a glossy surface, as in Norwich crepes, the object was to produce it without gloss, and very pliable and clothy. The best quality of challis, when finished with designs and figures, (either produced in the loom or printed,) was truly a splendid fabric, which commanded the attention of the higher circles, and became a favorite article of apparel at their fashionable resorts and parties. The worsted yarn for the weft of this article was spun at Bradford, from numbers 52's to 64's. The making of the challis fabric soon afterwards commenced in the north.—James's History of Woollen Manufacture.

CHALCEDONY. A hard mineral of the quartz family, often cut into seals. Under it may be grouped common chalcedony, heliotrope, chrysoprase, plumag, agate, belonging to the rhombohedral system, onyx, cat's eye, sardonyx, carnelian, and sard.

CHAMOMILE FLOWERS. The Anthemis nobilis of Linnaeus. The chamomile grows very abundantly in Cornwall, and some parts of England. It is cultivated at Mitcham and in Derbyshire, for the London market. The chamomile is used medicinally, and is employed by some brewers to substitute hops in bitter beer. It would be well if no more objectionable bitter were employed.

In 1856 we imported 72,751 lbs.

CHARCOAL. The fixed residuum of vegetables when they are exposed to ignition out of contact of air.

For the purpose of showing, within a limited space, the products of dry distillation of woof, the following list has been compiled for this work by the kindness of a friend engaged in those manufactures. For more specific information, see Destructive Distillation, and the articles enumerated under their special heads.

The only products of the dry distillation of wood at present of any commercial importance, are charcoal, acetic acid, naphtha, and, in a minor degree, tar and cresote.

The products of wood are, however, very numerous, and, when examined chemically, found to be very complex in character and constitution, many of them being very little understood.

They are gaseous, liquid, and solid.

The gaseous products are those not condensable by ordinary means, viz.:—

- Carbonic oxide.
- Carbonic acid.
- Light carburetted hydrogen, or marsh gas.
- Olefiant gas.
CHEESE.

These are usually employed (such as are combustible) for heating purposes in the manufactories where found. The liquid products are water, containing from 6% to 10% of dry acetic acid, ammonia, and, associated with them under the ordinary names of tar and naphtha, numerous oily, ethereal, and resinous bodies.

The following list will comprehend the greater number of these bodies:—

- Water
- Acetic acid in its crude state, called pyrogluic acid.
- Ammonia.
- Ordinary naphtha, or {Hydrate of methyl, syn. with spirit of wood and methyl alcohol.
- pyrogluic acid.
- Acete of methyl, or methyl acetic ether.
- Acetone, syn. with pyroacetic spirit.

Oils found in the crude

- Benzole.
- Toluole.
- Xylole.
- Naphthol.
- Cumoloe.

According to the researches of Cabhors these are all hydrocarbons, and separated by him from erudite spirit of wood.

From the distillation of tar are obtained, besides many of the foregoing, which would come under the name of "light oils," from their low specific gravity:

- Oils heavier than water, besides residuary resin or pitch—
  - Xylite.
  - Picmar.
  - Paraffine.
  - Mesite.
  - Cedr前期.
  - Capnomore.
  - Pittacal.

Solid Products: Pyroxanthine, Charcoal.—C. H. B. II.

CHEESE (composition of):—

<table>
<thead>
<tr>
<th>Ash of the substance</th>
<th>Nitrogen</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Normal</td>
<td>Dry</td>
</tr>
<tr>
<td>&quot; &quot; Parmesan</td>
<td>36.59</td>
<td>4.78</td>
</tr>
<tr>
<td>&quot; &quot; Neuchatel</td>
<td>61.87</td>
<td>4.25</td>
</tr>
<tr>
<td>&quot; &quot; Brie</td>
<td>53.99</td>
<td>5.63</td>
</tr>
<tr>
<td>&quot; &quot; Holland</td>
<td>41.11</td>
<td>6.21</td>
</tr>
<tr>
<td>&quot; &quot; Gruyere</td>
<td>32.05</td>
<td>4.79</td>
</tr>
</tbody>
</table>

Copper and its compounds:—

The term formula, in ordinary chemical language, is always understood to mean the collection of symbols indicating a compound substance. Thus, if we allude to the letter or letters indicating an element, we say its symbol; but if we are speaking of a compound, we say its formula. The symbols of all the elements will be found under the head of "ELEMENTS," vol. I. In constructing formula there are several rules to be observed, the neglect of which will lead to misapprehension of the meaning intended to be conveyed. Substances in the most intimate union are expressed by placing the symbols in juxta-position. Thus, oxide of lead is represented by PbO, dry sulphuric acid by SO₃, acetic acid by CH₃CO. But where a compound is to be expressed which is itself formed by the union of two compounds of the class first mentioned, such as an acid and a base, a comma is placed between them thus: Sulphate of lead is PbO,SO₃, nitrate of copper CuO(NO₃). The number of atoms, when more than one enters into a compound, is expressed by writing the number on the upper part of the right hand of the element. But if only one atom is to be expressed, the mere symbol is written. Thus, oxide of copper is CuO, but the sub-oxide is Cu₂O. If it be intended to multiply a formula not containing a comma or other sign, such as SO₃, CH₃CO., &c., the number is to be written on the left hand of the formula, and is to be made larger than would be the case if it merely multiplied the atoms of an element. Thus, two atoms of oxide of lead are written 2PbO, three atoms of acetic acid, 3CH₃CO. But it is to be remembered that a number placed on the left hand of a symbol or formula only multiplies as far as the first comma or sign, so that, if we wish to multiply a formula containing a comma or other sign, the formula must be placed between parentheses. Thus, two atoms of sulphate of lead are written (2PbO,SO₃). If it be intended to express the fact that one substance is to be added to another, with a view to the production of a given compound or reaction, the substances to be added together are connected by a plus sign. For example, suppose it be necessary to express the fact that one equivalent of oxide of lead added to one equivalent of sulphuric acid produces sulphate.
CHEMICAL FORMULAE.

of lead, we write, \( \text{PbO} + \text{SO}_3 \) forms sulphate of lead. But it is more usual and brief to put down the terms connected by the plus sign, followed by the sign of equality, and then the formula of the resulting compound, thus: \( \text{PbO} + \text{SO}_3 = \text{PbSO}_4 \). A collection of symbols expressing the nature of a reaction or decomposition, the two terms being united by the symbol of equality, is called an equation. Equations are of the highest value to the chemist, as enabling him to express in the simplest possible manner the most complicated reactions. Moreover, these equations enable us to see at a glance the true nature of a decomposition. To take a simple case, namely, that of the decomposition of tervalchloride of antimony by carbonate of ammonia, we have

\[
\text{SbCl}_3 + 3 (\text{NH}_4\text{CO}_3) = \text{Sb}_2\text{O}_3 + 2\text{NH}_4\text{Cl} + 3\text{CO}_2.
\]

Or, in words, tervalchloride of antimony plus three equivalents of carbonate of ammonia, yields one equivalent of teroxide of antimony, three equivalents of chloride of ammonium, and three equivalents of carbonic acid.

The above illustrations will suffice to show the principles upon which formulae and equations express the chemical decompositions are constructed. In writing equations showing the metamorphoses of substances with which it may be supposed the reader of them may not be very fully acquainted, it is proper to place beneath them the names of the substances in full; thus, in writing the change supposed to be experienced by amygdaline under the influence of a ferment which does not itself contribute any substance to the reaction, we might say:

\[
\text{C}_6\text{H}_3\text{NO}_3 + 4\text{H}_2\text{O} = \text{C}_6\text{H}_5\text{O}_3 + \text{C}_2\text{H}_5\text{N} + 2\text{C}_3\text{H}_6\text{O}_2
\]


In writing the formula of substitution compounds, it is convenient to place the replaced and replacing substances in a vertical line, so as to at a glance to indicate the substitution which has taken place. As an illustration, we shall place side by side the chemical type of ammonia and some bodies derived from it by substitution.

\[
\begin{array}{ccc}
\text{N} & \text{H} & \text{H} \\
\text{H} & \text{N} & \text{H} \\
\text{H} & \text{H} & \text{H}
\end{array}
\]


In the first of the above formulae we have the type or starting point, ammonia itself. In the next we find one atom of hydrogen (two volumes) replaced by one atom (two volumes) of the radical methyl. In the third we find two atoms of hydrogen replaced; and in the fourth illustration all three have been replaced by methyl. The fifth formula is that of ammonia, in which one equivalent of hydrogen is replaced by phenyl, forming phenylamine, or, as it is more usually termed, aniline. The sixth illustrates a very peculiar substitution. In it we find two atoms of hydrogen replaced by the platinicum of the late illustrious chemist, M. Gerhardt, who regards platinum as entering into substitutions with two atomic weights, as if it were two metals. The one being the platinum of chemists generally, its atomic weight being 99, (and its symbol Pt:) this he calls platinum. The other being platinicum, (pt,) with an atomic weight half that of platinum, namely, 49-5. The last formula is that of the singular base, triphosphamethylamine. In it we see the nitrogen of the original type replaced by phosphorus, and each equivalent of hydrogen by methyl.

It is a fruitful source of annoyance to students and others to find, on looking through chemical works, the same substance represented by different authors with totally different formulae. We shall endeavor to give a few instances and such explanations as will assist in enabling the student to overcome the difficulty. It is often the case that the differences in the formulae arise from the works consulted having been written at different dates; the older one is then, in most cases, to be rejected, because it is probable that the formula in it have been corrected by subsequent and more accurate researches. It not unfrequently happens that an author writes nitrous acid \( \text{NO}_2 \), and the true nitrous acid (\( \text{NO}_2 \)) is called hyponitrous acid. It may serve to assist the student in correcting any errors on this point, to consult a list of the oxides of nitrogen according to the nomenclature at present employed; for which, see some standard work on chemistry. A still more common cause of difficulty is owing to the different theoretical views of chemists regarding the constitution of chemical substances. The papers of MM. Laurent and Gerhardt, and the more advanced of their followers, are at times almost unintelligible to the beginner, owing to their adoption of different atomic weights to those employed in this country. Whatever opinion may be held by individuals respecting the necessity for the changes adopted by them, it must be remembered that the arguments in favor of their doctrines are in general of the most weighty kind; and, moreover, that chemical reactions can often be explained and generalized when
seen through the medium of their theoretical views, which present exceedingly embarrassing points if viewed under the old system. It will serve, to a great extent, to remove the difficulties alluded to, if it be remembered that, in order to pass from the ordinary atomic weights used in this work to those employed by M. Gerhardt, it is merely necessary to double the atomic weights of carbon, oxygen, sulphur, and selenium, while the hydrogen, nitrogen, phosphorous metals, chlorine, bromine, iodine, and fluorine remain unaltered.

Some of the more advanced chemists of the present day write carbonic acid $CO_2$, instead of $CO$. This is in consequence of regarding it as a dibasic instead of a monobasic acid. The same thing applies to sulphuric acid. It is also to be remembered that most modern chemists assume organic bodies to undergo a condensation to four volumes; consequently, ether becomes $C'H_2O_2$, instead of $C'H_2O$. The same remark applies to many other substances. Bodies that cannot have their vapor relations properly studied, in consequence of their not being volatile without decomposition, are often written in two or three different ways by various authors. It is probable that these anomalies will, for a time, increase rather than diminish, because recent discoveries are constantly showing the inadequacy of the older views of the chemical constitution of bodies to explain the reactions that occur.

It will greatly assist the student in his endeavors to recollect chemical formulæ, if he commits to memory the principal types and the substances which are regarded as formed on their model. The following are those which are best established:—

**Type, two atoms of water.**—This type is written in such a manner that the replacement of the hydrogen can be distinctly seen. By its side are placed a few of the substances formed on the same model.

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</thead>
<tbody>
<tr>
<td>$H_2O$</td>
<td>$H$</td>
<td>$O_2 \cdot C'H_2O_2$</td>
<td>$H$</td>
<td>$O_2 \cdot C'H_3$</td>
<td>$H$</td>
</tr>
</tbody>
</table>

In the above simple illustrations of the type water we have, in the case of acetic acid, one atom of hydrogen replaced by the oxidized radical acetyle $C'H_2O_2$, and the other by one atom of basic hydrogen. By basic hydrogen is meant, that it acts the part of, and can be replaced by, a metal. The opinions of chemists with regard to the nature of the radical existing in acetic acid are divided. Some consider the acid as the hydrated teroxide of the non-oxidized radical acetyle, $(C'H_3)$ and therefore write its formula $C'H_2O_2 + H_2O$. But as the chloride of the oxidized radical can be isolated, we cannot doubt its existence. Moreover, there is no doubt of the existence of the other radical, $C'H_3$, because we find it replacing hydrogen in the base acetylamine. But the conclusion must be drawn from these facts that there are two radicals, one existing in acetic acid, $C'H_2O_2$, which Williams calls ethyle; and another, sometimes called vinyle, $C'H$, which exists in aldehyde, in olefants, and several other bodies. The radical in acetic acid is, consequently, not $C'H_3$, but $C'H_2O_2$.

The next illustration is that of alcohol, which consists of two atoms of water, in which one atom of hydrogen is replaced by ethyle, and the other by hydrogen. Ether, on the other hand, is derived from the same type, both atoms of basic hydrogen being replaced by ethyle. Hydrate of potash and anhydrous potash will, after what has been said, explain themselves. It will be seen that in all these illustrations, the same vapor volume is preserved, and by this means the exceeding anomaly of ether and alcohol being of different vapor volumes is removed. While the type two atoms of water (= 4 volumes) has an actual existence, it remains for chemists to discover whether we are justified in receiving as types bodies which have no real existence, such as three atoms of water.

**Type, two atoms of hydrogen.**—The type ammonia has already been sufficiently illustrated; it remains, then, only to show what substances are to be regarded as formed on the type hydrogen. M. Gerhardt, in addition to these, adopts hydrochloric acid as a type; but when we consider that that acid is itself formed on the hydrogen model, it appears unnecessary to raise it to the dignity of a separate type.

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$H$</td>
<td>$C'H$</td>
<td>$C'H$</td>
<td>Cl</td>
<td>$C'H_3$</td>
<td>$CN$</td>
<td>$C'H$</td>
</tr>
</tbody>
</table>

The above will be sufficiently plain after what has been said, it being remembered that $C'H_2$ is methyl, $C'H$ ethyle, $C'H_3$ phenyle, and $CN$ cyanogen.

It is sometimes a source of perplexity to the beginner to find that the formula of salts are written by different authors in a somewhat different manner. Thus, sulphate of potash

*For the typical representation of the mixed and composed ethers, see the article Ethers.*
wily, by one, be written SO₃[KO, and by another SO₃K. The reason of this will become
plain from the following considerations:—All salts are derived from acids by the substitution
of metals for hydrogen. Thus, if instead of writing sulphuric acid SO₃H₂O we write
SO₃H, we shall at once see that sulphate of potash, SO₃K, is sulphuric acid in which one
equivalent of hydrogen is replaced by potassium. It is true that the relation between acids
and salts may be more completely seen by using a different class of formula, founded on
the theory of types; but, nevertheless, the above illustrations will serve to explain why one
person will write acetate of potash CΗ'O₄K, another CΗ'O₄O₂K, a third CΗ'O₄,KO, and
perhaps a fourth CΗ'O₄,KO².

On the modes of determining the empirical and rational formulae of substances from the
results of their analysis.—It now remains to show how the formulae of bodies are deter-
mained. There are two kinds of formula—the empirical and rational. An empirical for-
ma merely indicates the simplest ratio existing between the elements present; a rational
formula shows the absolute constitution of an atom or equivalent of any substance. Some-
times the expression rational formula is used in a more extended sense, and then signifies
the actual manner in which the elements are arranged in a compound molecule, but this
happens so seldom, that we shall in this work understand the term in the sense first given.

An empirical formula can always be deduced from the mere result of an accurate analy-
sis. A rational formula, on the other hand, demands a knowledge of the atomic weight of
the substance. The latter datum can be best determined—1st, by the analysis of a com-
pound with a substance the atomic weight of which is well established; 2d, by determining
the density of its vapor.

Empirical formula.—The percentage composition of a compound having been accu-
ately found, the empirical formula may be deduced from the following rule:—Divide the
percentage of each constituent by its atomic weight, and reduce the number so obtained to
its lowest terms. Suppose, for example, the empirical formula of nitric acid to be required,
the composition being:

| Nitrogen | - | 25-9 |
| Oxygen  | - | 74-1 |

100-00

These numbers, divided by their respective atomic weights, give:

\[
\frac{25-9}{14} = 1-85
\]

\[
\frac{74-1}{8} = 9-26
\]

To reduce these numbers to their lowest terms, it is merely necessary to divide 9-26 by
1-85. The simplest terms being:

| Nitrogen | 1-00: Oxygen, 5-00. |

Nitric acid consequently consists of one equivalent of nitrogen and five of oxygen.

Rational formula.—In the above illustration we found the simplest ratio existing be-
tween the elements of nitric acid. But it will be seen that, for such that appears there, it
may consist of n times NO₃. It becomes necessary, therefore, to find the atomic weight of
the acid, and then to find the number of atoms of the elements, (combined in the above
ratio,) which will make that atomic weight. In order to do this, it will be proper to deter-
mine the atomic weight of the acid from the data procured by the first method, given above.
In order to accomplish this, a salt was analyzed for the percentages of soda and nitric acid,
with the annexed result:

| Soda    | - | 36-47 |
| Nitric acid | - | 63-53 |

100-00

The required datum, namely, the atomic weight of the acid, can easily be obtained by
saying,—As the percentage of base is to the percentage of acid, so is the atomic weight of
the base to the atomic weight of the acid. In the instance given we have, therefore:

\[
\frac{36-47}{63-53} = \frac{31}{53-999}
\]

Percentage of | Percentage of | Atomic weight of | Atomic weight of
base. | acid. | base. | acid.

It is evident that 53-999 may be written 54-0 without any inaccuracy. If, therefore,
we add together the equivalents of nitrogen and oxygen in the ratio found in the empirical
formula, we shall have:
CHICORY.

1 equivalent of nitrogen = 14
5 equivalents of oxygen = 40

\[ \frac{54}{14} = 3.85714 \]

We will now consider the mode of determining the rational formula of a substance from the results of the analysis and the density of the vapor. Suppose a hydrocarbon to have yielded on analysis:

<table>
<thead>
<tr>
<th>Carbon</th>
<th>Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>85.714</td>
</tr>
<tr>
<td></td>
<td>14.286</td>
</tr>
<tr>
<td></td>
<td>100.000</td>
</tr>
</tbody>
</table>

The quotient being the same, the empirical formula becomes C\(n\)H\(m\). It remains, therefore, to determine the value of \(n\). The density of the vapor was found to be 2.9064. Now, the hydrocarbons always possess a condensation to four volumes.

For four volume formula the rule is:—Divide the density of the gas by half the density of hydrogen. Applying this rule, we have:

\[ \frac{2.9064}{0.0346} = 84.00 \]

It is, therefore, necessary to find what multiple of the atomic weight of CH will make 84.00. Now C\(+H = 6 + 1 = 7\), and \(7 \times 12 = 84\). Consequently the formula is 12(CH)\(n\), or, as it is always written, C\(9\)H\(8\).

The above rules will suffice to enable any person to determine the empirical and rational formula of substances from the results of analysis.—C. G. W.

CHICORY. The root of the Cichorium intybus. Wild Succory or Chicory. This plant is cultivated in various parts of England, growing well in a gravelly or chalky soil; also in Belgium, Holland, Germany, and France. The roots of the wild succory were formerly used medicinally; it possesses properties in many respects resembling those of the dandelion, but it is rarely employed for curative purposes in the present day.

Chicory root roasted has been employed as a substitute for coffee for more than eighty years. (Constantian Nachricht von d. Cichoriumwurzel, 1771.) It is now employed extensively as a mixture with coffee, which, although allowed, cannot be regarded other than an adulteration.

Chicory root is heated in iron cylinders, which are kept revolving as in the roasting of coffee. In this country about two pounds of hard are added to every cwt. of chicory during the roasting process; in France butter is used; by this a better and color resembling that of coffee are imparted to it. When roasted, the chicory is ground to powder and mixed with the coffee. Chicory has been supposed by some persons to be wholesome and nutritive, while others contend that it is neither one nor the other; however, no obvious ill effects have been observed to arise from its employment, if we except the occasional tendency to excite diarrhoea, when it has been used to excess. The analysis of chicory root by John gave 28 parts watery bitter extractive, 3 parts resin, besides sugar, sal ammoniac, and woody fibre. Walti procured inula from it, but the quantity varies greatly in different roots. The following remarks on the adulteration of chicory are by Dr. Pereira.

"Roasted chicory is extensively adulterated. To color it, Venetian red and perhaps, redlake are used. The former is sometimes mixed with the hard before this is introduced into the roasting machine; at other times it is added to the chicory during the process of grinding. Roasted pulse, (peas, beans, and lupinse,) corn, (rye and damaged wheat,) roots, (parsnips, carrots, and mangold wurzel,) bark, (oak-bark tan,) wood dust, (logwood and mahogany dust,) seeds, (acorns and horse chestnuts,) the mare of coffee, coffee husks, (called coffee-flights,) burnt sugar, baked bread, dog biscuits, and baked livres of horses and bullocks, (1) are substances which are said to have been used for adulterating chicory.

A mixture of roasted pulse (peas usually) and Venetian red has been used, under the name of "Hambro' powder," for the same purpose.

"The following are the chief modes of examining chicory with the view to the detection of these adulterations:—"

1st. Careful examination of the odor, flavor, and appearance to the naked eye of the suspected powder. In this way foreign substances may sometimes be detected.

2d. A portion of the dried powder is to be thrown on water; the chicory rapidly imbibes the water and falls to the bottom, whereas some intermixed powders (as the mare of coffee) float.

3d. The suspected powder is to be submitted to careful microscopical examination. Pulse and corn may be detected by the size, shape, and structure of the starch grains. The
tissues of bark, woods, and other roots may also be frequently distinguished from those of chicory.

"4th. A decoction of the suspected chicory is then to be prepared, and, when cold, to be tested with solution of iodine and persulphate of iron.

"Iodine colors a decoction of pure chicory brownish; whereas it produces a purplish, bluish, or blackish color with decoctions of roasted pulse, roasted corn, boiled bread, roasted acorns, and other substances containing starch. Persulphate or perchoride of iron does not produce much effect on a decoction of pure chicory, but it communicates a bluish or blackish tint to a decoction of oak-bark, of roasted acorns, and other substances containing tannic or gallie acids.

"5th. By infestation, pure dried chicory yields from 4 to 5 per cent. of a gray or fawn-colored ash. If Venetian red, or any other earthy or mineral substances, be present, no amount of ash is obtained. Moreover, when Venetian red has been employed, the color of the ash is more or less red."

CHINA CLAY. KAOLIN, or PORCELAIN CLAY, which see. A fine white clay produced by the decomposition of the felspar of the granite rocks. It is found and prepared in this country in Cornwall and Devonshire.

CHINA STONE. A semi-decomposed granite, (Petuntze,) which has nearly the same composition as the China clay, (see PORCELAIN CLAY.) "Indeed, the China clay can be considered as little more than this granite in a more advanced state of decomposition."—De la Roche.

The China stone is a kind of granite, the felspar of which has undergone a partial decomposition. It is carefully selected so as to be entirely free from school, and requires no other preparation for the market than to be broken into a size convenient for carriage. This granite is of a peculiar nature; it does not contain any mica, but numerous glossy scales of greenish-yellow tale. It has been stated by some authors that "this rock, (Pegmatite or Graphic granite,) after exposure to the decomposing action of the weather, is the chief source" of the China stone and clay. This represents but very imperfectly—indeed, incorrectly—the conditions. The decomposition of the granite is not brought about by the action of the weather, but by some peculiar decomposition proceeding to a considerable depth through the whole mass. In many places, from the very surface to the depth of more than 100 feet, this decomposition is equally apparent; and possibly it extends to much greater depths in some places. The same stone exposed to the air does not, in any ordinary time, exhibit any signs of disintegration. No satisfactory explanation has yet been offered of the conditions under which granite is decomposed to produce the Kaolin and the China stone.

There was an agreement existing amongst the producers of China stone to send off annually only 12,000 tons; but when the demand is brisk, this has been extended to 18,000 tons, and sometimes even more. The value of the China stone at the works in Cornwall is annually about £1,800. The whole that is raised is sent to the Staffordshire potteries.

CHLORIC ACID. This acid, which is only known in combination with one equivalent of water, is exceedingly unstable, being instantly decomposed by contact with organic matter; undergoing gradual spontaneous decomposition in diffused daylight, and being instantly decomposed, at a temperature of a little above 100° F., into chlorine, oxygen, and perchloric acid, the two former escaping as gases. It is prepared by decomposing chlorate of potash by the addition of hydrofluosilic acid, which forms with potash an insoluble compound.

CHLORINE, one of the most energetic of the undecomposed substances, exists, under ordinary circumstances, as a greenish-yellow gas; but, when exposed to a pressure of 4 atmospheres, it becomes a transparent liquid, which remains unfrozen even at the cold of—220° F. In the first state, its density, compared to air, (reckoned 1.000,) is 2.47; in the second, its density, compared to water, (1.000,) is 1.33. It is obtained either by the action of sulphuric acid on a mixture of common salt and binoxide of manganese, or by the action of moderately strong hydrochloric acid on binoxide of manganese alone. In the first case, the proportions are 7 parts by weight of oil of vitriol, previously diluted with 7 parts of water and 4 parts of common salt, intimately mixed with 3 parts of binoxide of manganese; in the latter, which is the most convenient method, hydrochloric acid, specific gravity 1:15 is gently heated with the finely powdered binoxide, in the proportions of about 3 oz. of oxide to half a pint of acid. The hydrochloric acid should not be more diluted than above indicated, otherwise an explosion may occur, probably in consequence of the formation of one of the explosive oxides of chlorine. The gas must be collected either over brine or over warm water.

In fumigating the Millbank Penitentiary, Mr. Faraday found that a mixture of one part of common salt and 1 part of binoxide of manganese, when acted upon by two parts of oil of vitriol previously mixed with one part of water, (all by weight,) and left till cold, produced the best results. Such a mixture at 60°, in shallow pans of red earthenware, liberated its
chlorine gradually, but perfectly, in four days. The salt and manganese were well mixed, and used in charges of 3½ pounds of the mixture. The acid and water were mixed in a wooden tub, the water being put in first, and then about half the acid; after cooling, the other half was added. The proportions of water and acid were 9 measures of the former to 10 of the latter.

In the year 1846, Mr. Pattinson patented an improved mode of manufacturing chlorine. In this process he made use of a stone vessel or generator, enclosed in a double iron vessel. The hydrochloric acid, specific gravity 1-16, is poured into the generator, and on a grating or false bottom is placed the binoxide of manganese in lumps. The temperature of the contents of the generating vessel is then raised to 180° F., by means of steam, made to circulate between the stone vessel and the iron casing. This heat is continued for about 18 hours, and then, by means of a suitable pipe passing to the bottom of the generator, steam, under a pressure of 10 lbs. to the inch, is injected into the vessel for about two minutes, and this is repeated every half hour for about six hours. In this process no mechanical agitation is required, as the steam enters with sufficient force, under the pressure above mentioned, to effect the requisite agitation of the contents, and, by clearing the lumps of manganese from all adhering matters, expose a fresh surface continually to the action of the acid.

In carrying this process into practical operation, Mr. Pattinson found that the apparatus is liable to be completely deranged, and the iron vessel destroyed by the action of the hydrochloric acid, if the stone generating vessel should happen to get broken; to obviate which inconveniences, and to enable the generator to be used though in a broken condition, the inner iron vessel is perforated, and the spaces between the two iron vessels, and between the inner iron vessel and the stone generator, are filled with coal tar, or pitch, thickened by boiling to such a consistence as to be tough, but not brittle, when cold.

Steam, circulating through a coil of pipe passing between the iron vessels, serves to maintain the tar at the requisite degree of heat; and in the event of the breakage of the stone generator, the liquefied tar flows into the fissure, and prevents the escape of the hydrochloric acid into the steam vessel.

A method of treating the residuum obtained in the manufacture of chlorine was patented in 1855 by Mr. C. Tennant Dunlop. It consists in transforming the chlorine of manganese, first into carbonate and then into oxide, by the action of heat. Whatever impurity the chlorine of manganese may contain—as chlorine of iron, for instance—is first separated, either by calcination or by the agency of a suitable precipitant. Practical working has shown that the carbonate of manganese thus treated yields an oxide of a richness equivalent to that of 85 per cent, pure peroxide. The carbonate of manganese may be obtained by precipitation from the chloride by carbonate of ammonia. The chloride of ammonium resulting from this treatment may either be employed as such, or it may be re-transformed in the usual way into carbonate for the precipitation of fresh chlorine of manganese. Hydrate of lime is also used as a precipitant, the resulting hydrated oxide of manganese being subsequently converted into carbonate by the transmission through it of a stream of carbonic acid.

By another process, carbonate of manganese is obtained by passing carbonic acid through the solution of chloride of manganese which has been previously mixed with a quantity of carbonate of soda. The carbonate of soda, under the influence of carbonic acid, decomposes the chloride of manganese into carbonate, from which the oxide can be obtained. The essential feature of this invention is the production of artificial oxide of manganese, by first converting the chloride into carbonate, and afterwards this latter into oxide, by the joint agencies of heat and atmospheric air.

CHLORIDE OF LIME. Mr. Graham found that hydrate of lime, dried at 212°, absorbed afterwards little or no chlorine; but that, when dried over sulphuric acid, it was in the most favorable condition for becoming chloride of lime. A dry, white, pulverulent compound is obtained by exposing the last hydrate to chlorine, which contains 41.2 to 41.4 chloride in 100 parts, of which 39 parts are available for bleaching, the remainder going to form chlorite of calcium and chlorate of lime. This appears to be the maximum absorption of chlorine by dry hydrate of lime; but the bleaching powder of commerce rarely, even when fresh prepared, contains more than 30 per cent. of chlorine, and after being kept for several months, the proportion often falls as low as 20 per cent. A compound containing one equivalent of chlorine and one equivalent of hydrate of lime, should contain 48-97 chloride and 51-43 hydrate of lime; a compound of one equivalent of chlorine and two of hydrate of lime, should contain 32-42 chlorine and 67-58 hydrate of lime; and these are about the proportions in good commercial specimens. It would not be advisable to attempt to manufacture a more highly chlorinated product, as the stability of the compound is increased by an excess of lime. Where a stream of chlorine is transmitted through water holding hydrate of lime in suspension, the lime is entirely dissolved, and the full equivalent of chlorine is absorbed. Water poured upon bleaching powder dissolves out the bleaching combination, leaving a large residue of lime. Ten parts of water are required for one part
CHLOROMETRY.

of dry chlorine. The solution emits the peculiar odor of hypochlorous acid; and if we regard bleaching powder as hypochlorite of lime, the reaction which occurs in its formation will be thus represented:—

$$2\text{CaO} + 2\text{Cl}_2 = \text{CaCl}_2 + \text{CaO}_2\text{Cl}_2.$$

But good bleaching powder is not deliquescent, neither does alcohol dissolve anything from it, both which should occur if the compound contained free chloride of calcium. It is possible, however, that the two salts may exist in bleaching powder in the form of a double salt, or that the chlorine is in direct combination with the oxide. If the compound be supposed to be pure chloride of lime, the reaction is simply an absorption of chlorine; and the same should be the case with the other bleaching compounds—chloride of soda, for instance. But when carbonate of soda, saturated with chlorine (Labarrague's Liquor) is evaporated, no chlorine is evolved, and the residue still possesses bleaching properties. The true nature of bleaching powder is open, therefore, to speculation.

The bleaching action of solution of chloride of lime is very slow unless an acid be added to it. When dilute sulphuric acid in insufficient quantity is employed, no chlorine is evolved but hypochlorous acid, which may be distilled off and condensed in a suitable receiver; but with excess of acid, chlorine only is liberated. When calces and other woven goods are to be bleached, they are first thoroughly cleansed by boiling successively with lime-water and a weak solution of caustic soda; they are then digested in a solution of bleaching powder, specific gravity 1.92, containing about 23 per cent. of chloride of lime; after which they are immersed in very dilute sulphuric acid, which, by liberating the chlorine within the fibres of the cloth, rapidly removes the color. The goods are then washed, a second time is readily in alkali, and again passed through a weaker solution of chloride of lime, and then through dilute acid; after which they are thoroughly washed in water. The quantity of liquor necessary for 700 lbs. of cloth is 97½ gallons, containing 38.5 lbs. of chloride. When white figures are required on a colored ground, the pattern is printed on the cloth with tartaric acid, thickened with gum. The color is discharged in those places where the acid was present, but elsewhere untouched. When chloride of lime is heated, it evolves oxygen gas, and sometimes chlorine, and it becomes converted into a mixture of chloride of lime and chloride of calcium, which has no bleaching properties. Half an ounce of chloride of lime boiled in two ounces of water yields, according to Keller, 165 cubic inches of oxygen contaminated with chlorine.

The property of chlorine to destroy offensive odors and to prevent putrefaction, gives to the chlorides of lime and soda a high value. On this important subject Pereira has the following remarks (Mat. Med. vol. I.) with reference to medical police. "If air be blown through putrid blood, and then through a solution of chloride of lime, carbonate of lime is precipitated, and the air is disinfected; but if the air be first passed through putrid blood, then through caustic potash, or milk of lime, to abstract the carbonic acid, and afterwards through the solution of chloride of lime, it retains its stinking quality. Chloride of lime may be employed to prevent the putrefaction of corpses previous to interment;—to destroy the odor of exhumed bodies during medico-legal investigations;—to destroy bad smells and prevent putrefaction in dissecting-rooms and workshops in which animal substances are employed (as cutout manufactories);—to destroy unpleasant odors from privies, sewers, drains, wells, docks, &c.; to disinfect ships, hospitals, prisons, stables, &c. The various modes of applying it will readily suggest themselves. For disinfecting corpses, a sheet should be soaked in a pailful of water containing a pound of chloride, and then wraped round the body. For destroying the smell of dissecting-rooms, &c., a solution of the chloride may be applied by means of a gardening pot." Of equal importance is this substance to the medical practitioner. "We apply them," observes Pereira, "to gangrenous parts, to ulcers of all kinds attended with foul secretions; to compound fractures accompanied with offensive discharges; in a word, we apply them in all cases accompanied with offensive and fetid odors. Their efficacy is not confined to an action on dead parts, or on the discharges from wounds and ulcers; they are of the greatest benefit to living parts, in which they induce more healthy action, and the consequent secretion of less offensive matters. Furthermore, in the sick chamber, many other occasions present themselves on which the power of the hypochlorites to destroy offensive odors will be found of the highest value: as to counteract the unpleasant smell of dressings, or bandages, &c., &c. In typhus fever a handkerchief, or a piece of calico, dipped in a weak solution of an alkaline hypochlorite, and suspended in the sick chamber, will be often of considerable service both to the patient and to the attendants." The poisonous exhalations from foul sewers may be counteracted by a slight inhalation of chlorine gas, as obtained from a little chloride of lime placed in the folds of a towel wetted with acetic acid. —H. M. N.

CHLOROMETRY. The processes or series of processes by which the strength or commercial value of substances containing chlorine, or from which chlorine may be rendered available, is ascertained, is called Chlorometry. Chloride (hypochlorite) of lime, of potash, or of soda, and the ores of manganese, are the most important of these substances. Chloride of lime is a mixture of hypochlorite of lime, chloride of calcium, and hydrate
of lime (CaO, ClO + CaCl + CaO, H₂O) and is decomposed by the weakest acids—even by carbonic acid; and therefore, by exposure to the air, it gradually loses its chlorine, and being converted into carbonate of lime, it may become perfectly valueless. This decomposition by all acids is common to all decolorizing chlorides (hypochlorites,) and may be explained, either by admitting that the decomposing acid (say, for example, the carbonic acid of the air) simply eliminates the hypochlorous acid, the oxygen of which oxidizes in a direct manner the calcium of the chloride of calcium mixed with the hypochlorite of lime, thus:

\[ \text{CaO, ClO} + \text{CaCl} + 2\text{CO}_2 = 2\text{CaO, CO}_2 + 2\text{Cl}; \]

or by considering the decolorizing chloride (chloride of lime, for example) not as a hypochlorite, but as a compound resulting from the direct combination of chloride with CaO(CaO, Cl⁻) in which view of the case the decomposition is explained as follows:

\[ \text{CaO, Cl} + \text{CO}_2 = \text{CaO, CO}_2 + \text{Cl}. \]

The value of the decolorizing chlorides in general, and of chloride of lime in particular, depends upon the quantity of chlorine which may be liberated from it under the influence of an acid. For technical purposes this estimation is exceedingly important, and should never be neglected by the bleacher.

Chlorine, whether in the free state, or combined with weak alkalies, or caustic lime, having the property of destroying coloring matter of an organic nature, this reaction was from the first resorted to as a means of determining the commercial value of these chlorides; namely, by ascertaining the quantity of a solution of indigo of known strength which could be decolorized by them; for this purpose a test liquor is prepared by dissolving a given quantity of sulphate of indigo in water, and pouring therein, drop by drop, a certain quantity of the sample of chloride of lime previously dissolved in a measured quantity of water. The solution of chloride of lime must be added, drop by drop, to the sulphate of indigo test liquor until the latter turns from blue to yellow, the operator taking care to stir the mixture without intermission.

This method of chlorometry, however, is objectionable, and is, in fact, the worst of all, on account of the difficulty of ascertaining when the reaction is complete; for the yellow color, resulting from the decomposition of the indigo, (chlorisatine,) mixing with the original blue color of the solution, produces a green color, which interferes with the correctness of the observation. On the other hand, the test liquor of sulphate of indigo always undergoes spontaneous and gradual decolorization by standing, not only when exposed to diffused light, but even though it be kept in well stoppered bottles, and in the dark.

The process generally adopted now is one which gives exceedingly accurate results; it was contrived by Gay-Lussac, and it is based on the property which arsenic acid (AsO₃) in solution in chlorhydric acid possesses of becoming peroxidized, that is to say, converted into arsenic acid (AsO₄), in the presence of chlorine and water. This reaction may be represented by the following equation:

\[ \text{AsO}_3 + 2\text{Cl} + 2\text{H}_2\text{O} = \text{AsO}_4 + 2\text{HCl}. \]

This reaction is so rapid, that, if organic substances capable of being decolorized by the action of chlorine are present while it is taking place, the color is not destroyed so long as any portion of arsenic acid remains unconverted into arsenic acid; but as soon as the last portion of the arsenic acid has been peroxidized, the liquid is instantly decolorized, which reaction at once indicates that the experiment is at an end.

Taking the equivalent of arsenious acid = 90, and that of chlorine = 35·5, it is evident that 99 grams of arsenious acid will correspond to 71·9 of chlorine (35·5 x 2 = 71·0) or, which is the same thing, 139·436 grams of arsenious acid will correspond very nearly to 100 of chlorine.

Take, therefore, a certain quantity of the arsenious acid of commerce, reduce it to powder, and dissolve it in hot diluted chlorhydric acid; allow it to recrystallize therefrom, wash the crystalline powder with cold water, dry it well, reduce it into fine powder, and of this dry and pure arsenious acid take now 139·44 grams, prepared as above said, put them into a flask, and add thereto about 3 ounces of pure chlorhydric acid, free from sulphurous and nitric acid, and diluted with three or four times its bulk of water; keep the whole at a boiling heat until all the arsenious acid has totally dissolved. Pour now the solution into a glass cylinder graduated into 10,000 grains-masses, rinse the flask with water, and pour the rinsings into the graduated glass cylinder until, in fact, it is filled up to the scratch marked 10,000. This done, it is clear that each 1,000 grains-mass of that liquor will contain 13·944 grains weight of arsenious acid, corresponding to 10 grains weight of chlorine. This should be labelled "arsenious acid test liquor." If it be desired to prepare a
CHLOROMETRY.

larger quantity of test liquor, instead of 139.44, the operator may take, for example, ten times that quantity of arsenious acid, namely, 1394.44 grains, (or, more correctly, 13.9436,) and dissolve them in as much liquid as will form 100,000 grains-measures; but he will have to take care to keep it in one or more well stoppered jars, in order that the strength of the solution may not be altered by evaporation.

Having thus prepared a quantity of arsenious acid test liquor, weigh off 100 grains from a fair average sample of the chloride of lime to be examined, and after triturating them first in the dry state, and then with a little water in a glass mortar, and then adding more water, pour the whole into a flask or glass vessel capable of holding 2,000 grains-measure, and marked with a scratch at that point. The mortar in which the chloride of lime has been triturated must be rinsed with more water, and the rinsings poured into the 2,000 grains-measure glass vessel first mentioned, until the whole of the 2,000 grains-measures are filled up to the scratch. The whole must now be well shaken, in order to obtain a uniformly turbid solution, and half of it (namely, 1,000 grains-measure) is transferred to an alkalimeter, which therefore will thus be filled up to 0, and will contain fifty grains of the chloride of lime under examination; and as the 1,000 grains-measure of the alkalimeter are divided into 100 degrees, each degree or division will therefore contain 0.5, or half a grain of chloride of lime.

On the other hand, pour also 1,000 grains-measure of the arsenious acid test liquor into a somewhat large beaker, and add thereto a few drops of a solution of sulphate of indigo, in order to impart a distinct blue color to it; shake the glass, so as to give a circular motion to the liquid, and while it is whirling round, pour gradually into it the chloride of lime liquor from the alkalimeter, watching attentively the moment when the blue tinge of the arsenious acid test liquor is destroyed. Care must be taken to stir the liquor well during the process, and to stop as soon as the decolorizing is effected, which indicates that the whole of the arsenious acid is converted into arsenic acid, and that the process is finished.

The quantity of chlorine contained in the sample is then determined in the following manner:

We have seen that the 1,000 grains-measure of the arsenious acid test liquor, into which the chloride of lime liquor was poured from the alkalimeter, contained 13.944 grains weight of arsenious acid, corresponding to 10 grains weight of chlorine. And the 1,000 grains-measure of chloride of lime liquor poured from the alkalimeter contained 50 grains weight of chloride of lime, each degree of the alkalimeter containing, therefore, half a grain of chloride of lime.

Let us suppose that, in order to destroy the blue color of the 1,000 grains-measure of the arsenious acid test liquor, 80 divisions (800 grains-measure) of the chloride of lime liquor in the alkalimeter have been employed. It is evident that these 80 divisions contained the 10 grains weight of chlorine necessary to destroy the color of the arsenious acid test solution, or rather to peroxidize all the arsenious acid (13.944) contained in that solution tinged blue with indigo. And since each division represents half a grain of chloride of lime, 40 grains weight of chloride of lime, containing 10 grains weight of chlorine, must have been present in the 80 divisions employed. If, now, 40 grains of the chloride of lime under examination contained 10 grains of chlorine, what is the percentage of chlorine in that same chloride? The answer is 25.

40 : 10 :: 100 : 25.

The chloride of lime submitted to the experiment contained, therefore, 25 per cent. of chlorine.

In the method just described it will be observed that, instead of pouring the arsenious acid test liquor into the solution of the sample, as in alkalimetry, it is, on the contrary, the solution of the sample which is poured into that of the test liquor. It is necessary to operate in this manner, because otherwise, the chlorhydric acid of the arsenious acid test liquor would disengage at once more chlorine than the arsenious acid could absorb, and thus render the result quite incorrect. On the contrary, by pouring the chloride of lime into the solution of arsenious acid, the chlorine being disengaged in small portions at a time, always meets with an abundance of arsenious acid to react upon. It is better, also, to employ the turbid mixture of chloride of lime, than to allow it to settle and to perform the experiment on the decanted portion.

Instead of arsenious acid, protosulphate of iron may very conveniently be employed; and this method, first proposed, I believe, by Runge, yields also exceedingly accurate results.

This method is based upon the rapid peroxidization which protosulphate of iron undergoes when in contact with chlorine in the presence of water and of free sulphuric acid, two equivalents of the protosulphate being thereby converted into one equivalent of persulphate, on account of one equivalent of chlorine liberating one equivalent of oxygen from the water, which equivalent of oxygen adds itself to the protoxide of iron which thus becomes converted into peroxide, and consequently into persulphate of iron, while the equiva-
CHLOROMETRY.

lent of hydrogen, liberated at the same time, forms with the chlorine one equivalent of chlorhydric acid; thus:

\[2\text{FeO}_7\text{SO}_4^2\text{+} + 2\text{SO}_4^2\text{+} + \text{HO} \rightarrow \text{Cl} = \text{FeO}_7\text{SO}_4^2\text{+} + \text{HCl};\]

by which it is seen that two equivalents of protosulphate of iron correspond to one equivalent of chlorine.

Protosulphate of iron may be obtained in a state of great purity as a by-product of the action of sulphuric acid upon protosulphuret of iron in the preparation of sulphuretted hydrogen, the evolution and reducing action of the latter gas preventing the formation of any peroxide. All the operator has to do is to redissolve in water, with addition of a little sulphuric acid, the crystals which have formed in the sulphuretted hydrogen apparatus, to filter the whole liquor and to recrystallize it; or else to pour the hot and very concentrated solution into strong alcohol: by the latter process, instead of obtaining the protosulphate in crystals, it is in the shape of a fine clear blue precipitate. Or else, as much piano-forte wire may be dissolved in moderately diluted sulphuric acid as will nearly neutralize it; the liquor is then filtered and left to crystallize, taking care, however, to leave a few fragments of the wire suspended in it, that no peroxidization may take place; or else the iron solution may be concentrated by heat, and while hot pour into strong alcohol, by which a clear blue crystalline precipitate of pure protosulphate of iron will be obtained. In either case the protosulphate of iron so produced contains 7 equivalents of water, or crystallization (FeO\(_7\)SO\(_4\)^2\text{+},\text{H}_2\text{O}.)

Take, accordingly, 2 equivalents, or 278 grains, of the crystallized protosulphate of iron, before alluded to, and previously dried between folds of blotting-paper, or moistened with alcohol, and left to dry in the air until all odor of alcohol has vanished, and dissolve these 278 grains of protosulphate of iron in water strongly acidified with either sulphuric or chlorhydric acid, so that the liquor may contain the bulk or volume of 3,550 grains of water. 1,000 grains of such a solution will therefore contain 78.31 grains of crystallized protosulphate of iron, and will accordingly be peroxidized by, or will correspond to, 10 grains of chlorine. When only one experiment is contemplated, 78.31 of crystallized protosulphate of iron may be at once dissolved in 1,000 grains (1 alkalimeter full) of water acidified with sulphuric acid; and this is the protosulphate of iron test liquor.

Weigh now 100 grains of the chloride of lime under examination, and dissolve them, as before mentioned, in a glass mortar, with a sufficient quantity of water, so that it may occupy the bulk of 2,000 grains-measures of water; pour half of this, namely, 1,000 grains-measure, into an alkalimeter, divided, as usual, into 100 divisions or degrees, each degree of which will therefore contain half a grain of chloride of lime. Pour gradually the chloride of lime from the alkalimeter into a glass beaker containing 1,000 grains-measure of the test solution of protosulphate of iron, above alluded to, stirring all the while, until it is completely converted into persulphate of iron, which may be ascertained by means of strips of paper, previously dipped into a solution of red prussiate of potash, and dried, more chloride of lime being poured from the alkalimeter as long as a blue stain is produced by touching the red prussiate of potash test paper with a drop of the solution of protosulphate of iron operated upon. The quantity of chloride contained in the chloride of lime under examination, is estimated as follows:—Since 1,000 grains-measure of the protosulphate of iron test liquor, into which the solution of chloride of lime is poured, contains, as we said, 78.31 grains of protosulphate of iron, corresponding to 10 grains of chlorine; and since, on the other hand, 1,000 grains-measure of the solution of chloride of lime in the alkalimeter contains 50 grains of chloride of lime, that is to say, \(\frac{1}{2}\) grain of that substance in each division of the alkalimeter.

Let us suppose, for example, that the quantity of chloride of lime required to peroxidize the iron of the 1,000 grains-measure of protosulphate amounts to 90 divisions, it is evident that the solution contained 45 grains of chloride of lime, and if these 45 grains of chloride of lime contained the 10 grains of chlorine necessary to peroxidize the iron of the protosulphate in the glass beaker, the 100 grains of the same chloride under examination evidently contain 22.22. This calculation is readily effected by dividing 1,000 by half the number of the divisions poured from the alkalimeter. The half of 90 (number of divisions employed) being 45, dividing 1,000 by 45 is 22.22.

Or, instead of 100 grains, the operator may take only 50 grains of the chloride of lime to be examined, and this will prove a more convenient quantity, in that case, the dividing 1,000 by the number of divisions employed, will at once give the percentage. Let us suppose, for example, that 45 divisions only of the 50 grains of chloride of lime solution, taken as sample, to have been employed; then, since these 45 divisions contained the 10 grains of chlorine necessary to peroxidize the iron contained in the 1,000 grains-measure of the protosulphate, it is evident that 100 grains will contain 22.22 of chlorine, thus:

<table>
<thead>
<tr>
<th>Divisions</th>
<th>Grains of Chlorine</th>
<th>Divisions</th>
<th>Grains of Chlorine</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>10</td>
<td>100</td>
<td>(x = 22.22)</td>
</tr>
</tbody>
</table>
CHLOROMETRY.

There are other accurate methods of determining the amount of chlorine in chloride of lime, provided a proper care be bestowed on the operation; but the processes by arsenious acid and by proto-sulphate of iron are by far the less liable to error from the circumstance, among other reasons, that their solutions are less liable to become altered. The other methods also require a longer time, and we shall only mention the rationale of their mode of action.

Thus the process by chloride of manganese consists in decomposing a test solution of it by the chloride of lime, to be examined as long as a brown precipitate is produced. The reaction is as follows:

\[
\begin{align*}
\text{MnCl}_2 + \text{CaO}_2\text{Cl} + \text{HO} &= \\
\text{MnO}_2 + \text{CaCl}_2 + \text{HCl}.
\end{align*}
\]

The process with yellow prussiate of potash depends upon the following reaction:

\[
(2\text{FeC}_2\text{y} + 2\text{KCl}) - \text{Cl} = \\
(\text{KCl} + \text{FeC}_2\text{y}) + \text{KCl}.
\]

That is to say, 2 equivalents of yellow prussiate (ferrocyanide of potassium) produce 1 equivalent of red prussiate, (ferricyanide of potassium), 1 equivalent of chloride of potassium; and, therefore, 2 equivalents of the yellow prussiate will correspond to 1 equivalent = 35.5 of chlorine. The chloride of lime is, as usual, poured into the solution of the chloride of manganese, and the operation is completed when a brown color begins to appear.

The process by subchloride of mercury, (Hg\textsubscript{2}Cl\textsubscript{2}) which is insoluble in water, is based upon its conversion by chlorine into chloride of mercury, (HgCl\textsubscript{2}) which is soluble in water, thus:

\[
\text{Hg}_2\text{Cl}_2 + \text{Cl} = \\
2\text{HgCl}.
\]

The method operanti is briefly as follows:—As substitute of mercury is difficult to obtain in a perfectly neutral state, and free from basic, or from pernitrate, take a known volume of pernitrate of mercury, precipitate it by an addition of chlorhydric acid, collect the precipitate formed, wash it, dry it at 221\textdegree F., and weigh it. Having thus ascertained the quantity of subchloride of mercury contained in the known bulk of pernitrate, 1,000 grains of it are measured off, and precipitated by an excess of chlorhydric acid, and the whole is then well shaken, so as to agglomerate it; a given weight of chloride of lime, say 50 grains, are dissolved, as usual, in water, so as to obtain one alkaliometer full, which is then gradually poured into the liquor containing the precipitated subchloride of mercury, until it completely disappears, and the liquor becomes as clear as water, which indicates that the operation is at an end. The number of divisions of the chloride of lime liquor used are then read off, and the quantity of chlorine present in the chloride of lime is easily calculated from the quantity of subchloride of mercury which was known to have existed in the known bulk of pernitrate employed, and which has been converted into perchloride of mercury by the chlorinated liquor poured into it.

Testing of Black Oxide of Manganese for its available Oxygen.

Manganese is found, in combination with more or less oxygen, in a number of minerals, but the principal ores of that substance are the pyrolusite, (bi-oxide of manganese,) MnO\textsubscript{2}, braunite, (sesquioxide of manganese,) MnO\textsubscript{2}, manganese, (hydrated sesquioxide of manganese,) MnO\textsubscript{2} + HO, hausmannite, (red oxide of manganese,) MnO\textsubscript{2} + kO, &c., &c.

The first, namely the pyrolusite, is by far the most important of these ores, which are chiefly employed for the preparations of chlorine, and their commercial value depends upon the quantity of this gas which a given weight of them can evolve, which quantity is proportionate to that of the oxygen contained in the ore beyond that which constitutes the protoxide of that metal, as will be shown presently. The manufacturer who uses these ores, ought also to take into consideration the amount of impurities which may be present in them, such as earthy carbonates, peroxide of iron, alumina, silica, sulphate of boryes, since these impurities diminish, pro tanto, the value of the ore. The estimation of the commercial value of a manganese ore may be accomplished in various ways.

One of these methods consists in first reducing into fine powder a sample of the ore, and treating it by moderately diluted nitric acid. If this produces an effervescence, it is owing to the presence of carbonates, and an excess of nitric acid should then be used, so as to dissolve them entirely. When all effervescence has ceased, even after a fresh addition of acid, the whole should be thrown on a filter and the residue within the filter should be washed and dried. For technical purposes, the weight of these carbonates may be thus easily effected, namely, by weighing a certain quantity of the sample, (for example 100 grains,) digesting it for a few hours in dilute nitric acid, collecting on a filter, washing, and drying until it no longer diminishes in weight. The loss indicates, of course, the quantity per cent. of the carbonates which it contained. This being done, take a weighed quantity
of the sample, dry it well, as just said, introduce it into a small counterpoised retort, at the extremity of which a tube containing fragments of fused chloride of calcium, also weighed, should be adjusted. Apply then to the retort the strongest heat that can be produced by an argand spirit lamp, or by my gas furnace-lamp, and, after some time, disconnect the chloride of calcium tube and weigh it. The increase of weight indicates the quantity of water which has volatilized, and which was yielded principally by the hydrate of sesquioxide, (manganese, MnO₂·H₂O) some portion of which is always found mixed with the peroxide; every grain of water thus evaporated corresponds to a 9:77 of manganese.

The contents of the small retort should now be emptied into a counterpoised platinum capsule or crucible, and ignited therein, until, after repeated weighings, the weight is observed to remain uniform; this converts the mass completely into manganoso-manganic oxide (MnO₄). The crucible is then weighed, and the loss indicates the quantities of oxygen evolved, from which that of the peroxide is calculated. Each grain of oxygen corresponds to 2:71 of pure peroxide. This experiment should evidently be carried on with great care, since a small quantity of oxygen represents a large quantity of peroxide.

In order to effect the complete conversion of the peroxide in the sample into red oxide of manganese, as above mentioned, the ignition should be continued for a long time, and the quantity operated upon should be small; if a larger quantity be treated, a common fire should be used instead of an argand lamp.

The value of manganese may also be very accurately estimated by measuring the quantity of chlorine which a given weight of the ore produces, when treated by chlorhydric acid.

In order to understand the rationale of this method, the reader must bear in mind that all the oxides of manganese, when heated in contact with chlorhydric acid, evolve a quantity of chlorine exactly proportionate to that of the oxygen above that which it contained in the protoxide. For example, protoxide of manganese being treated by chlorhydric acid, produces only protochloride of manganese, but yields no free chlorine, as shown by the following equation: MnO₄ + HCl = MnCl₂ + H₂O. Not so, however, the red oxide of manganese, or manganese-manganic oxide (MnO₄), which, when treated by chlorhydric acid, forms protochloride of manganese, but discengages one third of an equivalent of chlorine, as shown by the following equation: Red oxide of manganese, or manganoso-manganic oxide, may be represented by the formula MnO₂·MnO₃, or by MnO₄, or by 3MnO₃·2H₂O; therefore: 14MnO₄ + 14HCl = 14MnCl₂ + 7Cl₂ + 7H₂O.

Sesquioxide of manganese, when treated by chlorhydric acid, yields half an equivalent of free chlorine for each equivalent of protochloride of manganese formed; as shown by the following equation: Sesquioxide of manganese, MnO₂, is the same as 2MnO₃; therefore 14MnO₂ + 14HCl = 14MnCl₂ + 7Cl₂ + 7H₂O.

Lastly, peroxide of manganese, when treated by chlorhydric acid, yields one entire equivalent of chlorine for each equivalent of protochloride formed, as shown by the following equation: Peroxide of manganese is MnO₂; therefore MnO₂ + 2HCl = 2MnCl₂ + Cl₂ + H₂O. And as the commercial value of the ores of manganese depends, as already said, upon the amount of chlorine which they can evolve when treated by chlorhydric acid, the object in view will evidently be attained by determining that quantity.

Runge's method, which we detailed at the beginning of this article in the testing of chlorine of lime, may also be applied for the testing of the ores of manganese. That method, it will be recollected, is based upon the rapid peroxidization which sublate of protoxide of iron undergoes when in contact with chlorine, water being present, which reaction is represented as follows: 2FeO·SO₃ + HO + Cl = Fe₂O₃·SO₄ + HCl. Showing that two equivalents of protosulphate of iron represent one equivalent of chlorine, since one equivalent of chlorine is required to convert two equivalents of protosulphate of iron into one of the persulphate of that base. The experiment is performed as follows: Pulverize 278 grains (2 equivalents) of crystalized protosulphate of iron, (2FeO·SO₃·2H₂O) and mix them in a small flask with 43½ grains of the manganese under examination, and previously reduced into very fine powder. These 43½ grains represent one equivalent of pure binoxide of manganese, (MnO₂) and would, therefore, if pure, peroxidize exactly the two equivalents, or 275 of protosulphate of iron. About three fluid ounces of strong chlorhydric acid should now be poured upon the mixture in the flask, which flask must be immediately closed with a perforated cork, provided with a tube-funnel drawn to a point, in order that the vapor may escape, and the whole is then rapidly boiled. The chlorine discengaged by the manganese is immediately absorbed by the protosulphate of iron. We just said that 43½ grains of peroxide of manganese would, if pure, exactly peroxidize the 275 grains of protosulphate of iron, but as the peroxide of manganese of commodities is never pure, it is evident that the 43½ grains of the sample employed will prove insufficient to peroxidize the iron, and hence, the necessity of ascertaining the amount of protosulphate which could not be peroxidized, and which remains in the acid solution. This may be done by means of a chlorate of potash test-liquor, as follows: Since 1 equivalent (≈129·5 grains) of chlorate of potash (≈K₂O·ClO₃) produce, under the influence of boiling chlorhydric acid, 6 equivalents of chlorine, as
CHLOROMETRY.

shown by the equation : \( \text{K}_2\text{ClO}_3 + 6\text{HCl} = 2\text{KCl} + 3\text{Cl}_2 + 6\text{H}_2\text{O} \), it follows that 20-41 of chlorate of potash would be sufficient to peroxidize 278 grains (2 equivalents) of protosulphate of iron, and would therefore represent 35-5 (1 equivalent) of chlorine, or 43-6 of peroxide of manganese.

The chlorate of potash test liquor, therefore, is prepared by dissolving 20-41 of chlorate of potash in 1,000 water-grains' measure of water. The solution is then poured carefully, drop by drop, from a glass alkaliometer through the tube funnel into the boiling hot solution containing the salt of iron. The whole of the chlorine which is disengaged is immediately absorbed by the protosulphate of iron, but as soon as the latter is completely peroxidized, the free chlorine which is evolved immediately reacts upon the coloring matter of a slip of paper, stained blue by sulphate of indigo, or litmus, previously placed by the operator between the cork and the neck of the flask, which piece of paper becoming bleached indicates that the operation is terminated. The operator then reads off the number of measures of the chlorate of potash test liquor which have been employed to complete the peroxidization of the protosulphate of iron.

Let us suppose that 50 divisions of the alkaliometer (500 water-grains' measures) have been employed; it is clear that half the quantity only of the protosulphate of iron employed has been converted into persulphate, and that consequently the quantity of the sample of manganese contained half its weight of valueless material; or, in other words, each measure of the test solution of chlorate of potash employed to complete the peroxidization of the protosulphate represents 1 per cent. or 21-8 grains of useless matter contained in the 43-6 grains of the ore of manganese operated upon. The air should be excluded from the flask during the peroxidization of the protosulphate of iron, else the oxygen of the air acting upon the salt of iron, would peroxidize a portion of it and vitiate the result. Instead of protosulphate, protochloride of iron may be used, for which purpose 56 grains (2 equivalents) of plano-forte wire should be put into a matrix or flask as above mentioned, and about four fluid ounces of pure concentrated chlorhydric acid poured upon them. The flask being closed, as directed in the preceding process, with a cork provided with a funnel tube drawn to a point at the lower end, a gentle heat is then applied to promote the solution of the iron. When all the metal has dissolved, the operator introduces 43-6 grains of the peroxide of manganese under examination, previously reduced into fine powder and kept in readiness, weighed and folded up in a piece of paper; the flask is immediately closed with its cork, the liquor is slightly agitated and then brought to the boiling point. The chlorine disengaged by the manganese is completely absorbed by the protochloride of iron, the excess of which is determined by the chlorate of potash test liquor precisely as explained just above.

By the methods which we have described the proportion of chlorine which a sample of manganese can evolve may be ascertained, but this alone is far from constituting the commercial value of the article as a source of chlorine, and it is not less important to determine the proportions of the other substances, such as peroxide of iron, earthy carbonates, &c., which are contained in the sample, and which unprofitably consume a certain quantity of hydrochloric acid without evolving chlorine, and merely producing chlorides of iron, of calcium, of barium, &c. Hence the necessity of estimating not only the quantity of chlorine which a given weight of peroxide of manganese can yield, but likewise the proportion of hydrochloric acid which is uselessly saturated by the foreign substances contained in the ore. For this purpose the following method, which was first recommended by Gay-Lussac, may be resorted to:—One equivalent, or 43-6 grains, of the peroxide of manganese under examination are treated by an excess of hydrochloric acid; for example, by 500 water-grain measures of chlorhydric acid of specific gravity 1-995, which quantity contains, according to Dr. Ur, 109 grains of real acid. The amount of chlorine corresponding to that of the pure manganese in the sample is then determined as mentioned before by means of protosulphate or protochloride of iron.

Since 43-6 grains (one equivalent) of pure peroxide of manganese require 74 grains (two equivalents) of pure chlorhydric acid to evolve 35-5 of chlorine, if we saturate the excess of chlorhydric acid employed by means of a solution of carbonate of soda, as in acidityometry, and thus determine the quantity of free acid, the difference will at once show what quantity of acid has been consumed both by the peroxide of manganese and by the foreign substances conjointly; but if we now subtract from that number the quantity consumed by the manganese, which will have been ascertained in the first part of the experiment, the remainder will, of course, represent the proportion which has been uselessly consumed by the impurities.

Taking a test solution of carbonate of soda of such a strength that 100 alkalimetric divisions contain exactly 83 grains (one equivalent) of it, and are consequently capable of saturating exactly 36-5 grains (one equivalent) of pure chlorhydric acid, let us suppose that in order to saturate the excess of free acid left after the determination of the chlorine evolved by the manganese, it is found that 140 alkalimetric divisions of the test solution of carbonate of soda just alluded to have been required. Since 100 alkalimetric divisions
or measures of carbonate of soda can saturate 30·5 grains of pure chlorhydric acid, the 140 divisions or measures employed represent, therefore, 51·1 grains of acid left in excess and in a free state, which being deducted from the 100 grains (contained in the 500 grain measures of acid of specific gravity 1·093 employed) leave 48·9 grains as the proportion of real acid consumed by the manganese and impurities of the sample. Let us suppose, now, that the 43·6 grains of manganese operated upon have been found in the first part of the experiment to contain only 21·8 grains, or 50 per cent. of peroxide of manganese as before mentioned; these will, therefore, have consumed 36·6 grains of chlorhydric acid, which being deducted from the 48·9 grains, (the joint quantity of acid consumed by the acid and impurities) leave 12·4 as the proportion of pure chlorhydric acid wasted or uselessly taken up by the impurities alone, and therefore the 43·6 grains of peroxide of manganese operated upon consisted of

<table>
<thead>
<tr>
<th>Pure peroxide of manganese</th>
<th>Impurities unprofitably consuming chlorhydric acid</th>
<th>Other impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21·8</td>
<td>12·4</td>
<td>9·4</td>
</tr>
</tbody>
</table>

\[\text{Total} = 42·6 = 100\%\]

The amount of water contained in the sample may be separately estimated by exposing a given weight of it (100 grains, for example) in a capsule, at a temperature of about 215° Fahr. until they no longer lose weight. The loss, of course, indicates the percentage of water.

The economy of any sample of manganese in reference to its consumption of acid, in generating a given quantity of chlorine, may be ascertained by the oxalic acid test:—44 grains of the pure peroxide, with 93 grains of neutral oxide of potash, and 98 of oil of vitriol disengage 44 grains of carbonic acid, and afford a complete neutral solution; because the one half of the sulphuric acid, =49 grains, goes to form an atom of sulphate of manganese, and the other half to form an atom of sulphate of potash.

The deficiency in the weight of carbonic acid thrown off will show the deficiency of peroxide of manganese; the quantity of free sulphuric acid may be measured by a test solution of bicarbonate of potash, and the quantity neutralized, compared to the carbolic gas produced, will show by the ratio of 98 to 44, the amount of acid unprofitably consumed.—A. N.

CHLOROPHANE. A name given to some of the varieties of flour spar. See Filler Spar.

CHROMATES OF POTASH. (For the preparation of these salts, refer to Chrome Iox.) Bichromate of potash, by slow cooling, may be obtained in the form of square tables, with bevelled edges, or flat, four-sided prisms. They are permanent in the air, have a metallic and bitter taste, and dissolve in about one-tenth of their weight of water at 60° F., but in one half of their weight of boiling water. The composition of bichromate of potash is

\[
\begin{align*}
\text{Potash} & \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad 81 \cdot 6 \\
\text{Chromic acid} & \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad 68 \cdot 4 \\
\end{align*}
\]

That of the neutral Chromate of Potash is

<table>
<thead>
<tr>
<th>Potash</th>
<th>Chromic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>48·9</td>
<td>52·0</td>
</tr>
</tbody>
</table>

These salts are much employed in Calico Printing and in Dyeing, which see.

The value of a solution of chromate of potash, if it be tolerably pure, may be inferred from its specific gravity by the following table:

<table>
<thead>
<tr>
<th>At specific gravity</th>
<th>Contains about 30 per cent of the salt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1·12</td>
<td>1·21</td>
</tr>
<tr>
<td>1·13</td>
<td>1·11</td>
</tr>
<tr>
<td>1·15</td>
<td>1·10</td>
</tr>
<tr>
<td>1·16</td>
<td>1·09</td>
</tr>
<tr>
<td>1·18</td>
<td>1·07</td>
</tr>
<tr>
<td>1·20</td>
<td>1·05</td>
</tr>
</tbody>
</table>

In making the red bichromate of potash from these solutions of the yellow salt, nitric acid was at first chiefly used; but in consequence of its relatively high price, sulphuric, muriatic, or acetic acid has been frequently substituted upon the large scale.

CHROMATE OF LEAD, the chrome yellow of the painter, is a rich pigment of various shades, from deep orange to the palest canary yellow. It is made by adding a limpid solution of the neutral chromate of potash, to a solution, equally limpid, of acetate or nitrate of lead. A precipitate falls which must be well washed and carefully dried out of the reach of
any sulphuretted vapors. A lighter shade of yellow is obtained by mixing some solution of alum or sulphuric acid with the chromate before pouring it into the solution of lead; and an orange that is to be procured by the addition of subacetate of lead in any desired proportions. It was ascertained by MM. Riot and Delisse, that the proportion of chromic acid in chromate of lead may be much diminished without any injury to the color, and that the same color is produced with 25 parts of neutral chromate for 100 of chrome yellow, as when 34 parts are used. They give the following formulas for the preparation of this pigment. Acetate of lead is dissolved in water, and sulphuric acid in quantity necessary to convert the oxide of lead into sulphate is added. The clear liquid contains acetic acid, and may be drawn off and reserved for the preparation of fresh acetate of lead. The sulphate of lead is washed and treated with a hot solution of neutral chromate of potash, 25 parts being used for every 75 parts of sulphate of lead. The liquid then contains sulphate of potash which may be made available, and the precipitate consists of chromate of sulphate of lead.

To prepare chrome red, Rongé directs an intimate mixture to be made of 448 lbs. of litharge, 60 lbs. of common salt, and 500 lbs. of water. As soon as the mass becomes white and swells up considerably, more water is added to prevent it from becoming too hard. After four or five days, the mass becomes a compound of chloride and hydrated oxide of lead. Without separating the mother liquor, which contains undecomposed chloride of sodium and soda, 150 lbs. of powdered bichromate of potash are to be added, and the whole well stirred together, and finally washed.

Liebig and Wöhler have lately contrived a process for producing a subchromate of lead of a beautiful vermillon hue. Into saltpetre, brought to fusion in a crucible at a gentle heat, pure chrome yellow is to be thrown by small portions at a time. A strong ebullition takes place at each addition, and the mass becomes black, and continues so while it is hot. The chrome yellow is to be added till little of the saltpetre remains undecomposed, care being taken not to overheat the crucible, lest the color of the mixture should become brown. Having allowed it to settle for a few minutes, during which the dense basic salt falls to the bottom, the fluid part, consisting of chromate of potash and saltpetre, is to be poured off, and it can be employed again in preparing chrome yellow. The mass remaining in the crucible is to be washed with water, and the chrome red being separated from the other matters, it is to be dried after proper edulcoration. It is essential for the beauty of the color, that the saline solution should not stand long over the red powder, because the color is thus apt to become of a dull orange hue. The fine crystalline powder subsides so quickly to the bottom after every ablation, that the above precaution may be easily observed.

**CHROME IRON.** The only ore of chromic which occurs in sufficient abundance for the purposes of art, is the octahedral chrome ore, commonly called chromate of iron, though it is rather a compound of the oxides of chromium and iron. The fracture of this mineral is imperfect conchoidal, or uneven. Hardness=5·5; specific gravity 4·4 to 4·5; but the usual chrome ore found in the market varies from 3 to 4. Its lustre is semi-metallic or resinous; color, iron, or brownish black; streak, yellowish to reddish brown. It is sometimes magnetic. Before the blowpipe it is infusible alone, but in borax it is slowly soluble, forming a beautiful emerald green bead; fused with nitre it forms a yellow solution in water.

Chrome ore was first discovered in the Var department in France; it is also found in Saxony, Silesia, Bohemia, and Styria; in Norway at Bønns; in the Ural near Katherinenberg; in the United States at the Berkshire near Baltimore, Chester in Massachusetts, and Hoboken in New Jersey. In Scotland it is found in the parishes of Kildrum and Towie in Aberdeenshire; in the limestone near Portsoy in Banffshire; near Ben Lawes in Perthshire, and at Buchanan in Stirlingshire. It occurs massive and in considerable quantity at Swinness, and Haroldswick in Unst, one of the Shetlands; also in Fetlar and in other of the smaller Shetland Islands.

**Composition of Chrome Iron Ores.**

<table>
<thead>
<tr>
<th></th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoxide of Chromium</td>
<td>36·0</td>
<td>54·08</td>
<td>39·51</td>
<td>60·04</td>
<td>43·00</td>
</tr>
<tr>
<td>Protosxide of Iron</td>
<td>27·0</td>
<td>25·86</td>
<td>36·00</td>
<td>20·13</td>
<td>34·70</td>
</tr>
<tr>
<td>Alumina</td>
<td>24·5</td>
<td>9·08</td>
<td>18·90</td>
<td>11·85</td>
<td>20·30</td>
</tr>
<tr>
<td>Magnesia</td>
<td>5·86</td>
<td>7·45</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Silica</td>
<td>5·9</td>
<td>4·83</td>
<td>10·90</td>
<td>-</td>
<td>2·90</td>
</tr>
</tbody>
</table>

(1) From St. Domingo, analyzed by Berthier; (2) from Bønns, in Norway, analyzed by Van Kobell; (3) from Baltimore, analyzed by Seybert; (4) crystallized, from Baltimore, analyzed by Alcock; (5) analyzed by Klaproth.
The chief application of this ore is to the production of Chromate of Potash, from which salt the various other preparations of this metal used in the arts are obtained.

Treatise of the Ore.—According to the old method, it is reduced to a fine powder, by being ground in a mill under ponderous edge wheels, and sifted. It is then mixed with one third or one half its weight of coarsely-bruised lime, and exposed to a powerful heat for several hours, on a reverberatory hearth, where it is stirred about occasionally. In the large manufactories of this country, the ignition of the above mixture is put in pots laid aside as too operose and expensive. The calcined matter is raked out and lixiviated with water. The bright yellow solution is then evaporated briskly, and the chromate of potash falls down in the form of a granular salt, which is lifted out, from time to time, from the bottom with a large ladle, perforated with small holes, and thrown into a draining box. The saline powder may be formed into regular crystals of neutral Chromate of Potash, by solution in water and slow evaporation: or it may be converted into a more beautiful crystalline body, the bichromate of potash, by treating its concentrated solution with nitric, muriatic, sulphuric, or acetic acid, or indeed any acid exercising a stronger affinity for the second atom of the potash, than the chromic acid does.

The first great improvement in this manufacture was the dispensing with nitre, and oxidizing entirely by means of air admitted into the reverberatory furnace, in which the ore mixed with carbonate of potash is calcined: Stromeyer afterwards suggested the addition of lime, by which the oxidation was much quickened, and Mr. Charles Watt substituted the sulphates of potash and soda for the nitrates of those alkalies. The sulphate was first intimately mixed with the ground ore, and then the lime well incorporated with the mixture, which was heated to bright redness for four hours, with frequent stirring.

In 1847 Mr. Titchmarsh obtained a patent for the use of felspar in the manufacture of certain alkaline salts, and amongst them of chromate of potash: he directs 4 parts by weight of felspar, 4 parts of lime, or an equivalent quantity of carbonate of lime, and one part of chrome ore, all in fine powder, to be intimately mixed together, and kept at a bright red heat for from 18 to 20 hours in a reverberatory furnace, the mixture being turned over frequently, so that all parts may be exposed equally to heat and air; the temperature is not to rise high enough to cause even incipient fusion; and the charge should be kept in a porous state; when, on being examined, the charge is found to contain the proper quantity of alkaline chromate, it is withdrawn from the furnace, and lixiviated with water.

Mr. Swindell mixes the powdered ore with an equal weight of common salt, muriate of potash, or hydrate of lime, and exposes the mixture to a full red heat, passing over it while in fusion, highly heated steam, and stirring it every 10 or 15 minutes: the hydrochloric acid and iron escape in the form of sesquichloride of iron.

In treating chromium, (chromate of iron,) the ore is pulverized and mixed with common salt, muriate of potash, or hydrate of lime, and exposed in a reverberatory furnace to a red or even a white heat, the mixture being stirred every ten or fifteen minutes, and steam at a very elevated temperature introduced during the operation, until the desired effect is obtained, which may be ascertained by withdrawing a portion from the furnace and testing it, as customary. The products of this operation are finally treated in the manner usual for the chromic and bichromic salts.

The mixture of chromic and common salt produces chromate of soda, the greater portion, or perhaps all of the iron contained in the chromium being absorbed by the hydrochloric acid evolved from the salt, and carried off in the form of sesquichloride of iron. From the first mixture is manufactured pure bichromate of soda, which, by the addition of hydrochloric acid, may be converted to chlorochromate; and from the last, or lime mixture, is produced a chromate of that earth, from which, by the addition of soda or potash, there may be obtained a compound salt, which, with those previously mentioned, may be advantageously employed.

M. Jacquelin first prepares chromate of lime by calcining at a bright red heat in a reverberatory furnace, for 9 or 10 hours, an intimate mixture of chalk and chrome ore. The friable and porous mass is then crushed, suspended in water, and sulphuric acid added until the liquid slightly reddens blue litmus paper; the chromate of lime is hereby converted into bichromate; chalk is now added, until the whole of the sesquioxide of iron is precipitated, and the clear liquid, which now contains only bichromate of lime and little sulphate, may be used for the preparation of the insoluble chromates of lead, zinc, baryta, &c., by mixing it with the acetates or chlorides of these metals. To prepare bichromate of potash, the bichromate of lime is mixed with solution of carbonate of potash, which gives rise to insoluble carbonate of lime, which is easily washed, and a solution of bichromate of potash which is concentrated and set aside to crystallize.

Mr. Booth (patent sealed Nov. 9th, 1823) mixes powdered chrome ore with one-fifth of its weight of powdered charcoal, and heats it on the hearth of a reverberatory furnace, protecting it carefully from the air. The ore is by this means decomposed, and the iron reduced to the metallic state, and is dissolved out by dilute sulphuric acid; the residue is washed and dried, and afterwards mixed with carbonate of potash and saltpetre, and heated
CHROMIUM, OXIDE OF.

337

in the same manner that the chrome ore itself is heated in the process usually employed. The solution of sulphate of iron is evaporated to crystallization so as to produce copperas in a state adapted for commerce.

Analysis of Chrome Iron Ore.—Various methods have been proposed. The following, suggested by Mr. T. S. Hunt, gives accurate results:—The ore, finely levigated in an agate mortar, is mixed with 10 or 12 times its weight of fused bisulphate of potash, and preserved at a gentle heat for about half an hour. The fused mass is extracted with hot water, and boiled for a few minutes with excess of carbonate of soda; the precipitate is dried and fused with five times its weight of a mixture of equal parts of nitre and carbonate of soda, in a platinum or silver crucible. The mixture is kept in fusion for 10 or 15 minutes, and when cold, is extracted with water. The alkaline chromate thus obtained may be precipitated by a salt of lead, or it may be supersaturated by hydrochloric acid, and boiled with alcohol, by which it is converted into chloride of chromium, from which the oxide is to be precipitated by adding ammonia in excess and boiling for a few minutes. Chrome iron ore is so difficult of decomposition, that the method of fusing it at once with nitre and an alkaline carbonate frequently fails in oxidizing the whole of the chromium into chromic acid.

Mr. Calvert mixes the well-pulverized ore with three or four times its weight of a mixture made by slaking quicklime with caustic soda, and then dries and calcines the mass. He then adds one-fourth part of nitrate of soda, and calcines for two hours more, by which time he finds the whole of the chromium is converted into chromic acid. Another process, which Mr. Calvert finds to produce good results, consists in calcining the pulverized chrome ore with nitrate of baryta, adding a little caustic potash from time to time towards the end of the process.—H. M. N.

CHROMIC ACID. There are several methods of preparing this acid; the simplest consists in decomposing bichromate of potash by oil of vitriol:—1. An excess of oil of vitriol is mixed with a warm solution of bichromate of potash, the liquid is poured off from the chromic acid, which separates in small red crystals; the crystals are drained in a funnel having its stem partly filled with coarsely pounded glass, and are afterwards dried on a porous tile under a bell-glass. 2. Mr. Warrington mixes 10 measures of a cold saturated solution of bichromate of potash with from 12 to 15 measures of oil of vitriol free from lead, and presses the red acicular crystals, which separate as the liquid cools, between porous stones. If it be desired to remove the last traces of sulphuric acid, the crystals should be redissolved in water, and a solution of bichromate of baryta should be added in quantity just sufficient to throw down the whole of the sulphuric acid as sulphate of baryta; the solution may be recrystallized by evaporation in vacuo. 3. Meissner prepares the acid direct from chromate of baryta by digesting that salt with a quantity of dilute sulphuric acid, not sufficient for complete saturation; the solution which contains chromic acid and acid chromate of baryta is precipitated by the exact amount of sulphuric acid required, so that the solution is neither affected by sulphuric acid, nor by a salt of baryta; it is then evaporated to dryness.

CHROMIUM. The metallic base of the oxide of chromium. It may be obtained by exposing to a very high temperature, in a crucible lined with charcoal, an intimate mixture of sesquisulphide of chromium and charcoal. The spongy mass obtained is powdered in an iron mortar and mixed with a little more sesquisulphide of chromic acid, and so well mixed that all the carbon is as nearly as possible in the carbon; it is then again exposed in a porcelain crucible to a very high temperature, when a coherent metal is obtained. This metal is grayish in color, hard, brittle, and magnetic at low temperatures. It has received no practical applications.

CHROMIUM, OXIDE OF. The green oxide of chromium has come so extensively into use as an enamel color for porcelain, that a fuller account of the best modes of manufacturing it must prove acceptable to many of our readers.

That oxide, in combination with water, called the hydrate, may be economically prepared by boiling chromate of potash, dissolved in water, with half its weight of flowers of sulphur, till the resulting green precipitate ceases to increase, which may be easily ascertained by filtering a little of the mixture. The addition of some potash accelerates the operation. This consists in combining the sulphur with the oxygen of the chromic acid, so as to form sulphuric acid, which unites with the potash of the chromate into sulphate of potash, while the chrom oxide becomes a hydrate. An extra quantity of potash facilitates the dehydration of the chromic acid by the formation of hyposulphite and sulphur of potash, both of which have a strong attraction for oxygen. For this purpose the clear liquor of the chromate of potash is sufficiently pure, though it should hold some alumina and silice in solution, as it generally does. The hydrate may be freed from particles of sulphur by heating dilute sulphuric acid upon it, which dissolves it; after which it may be precipitated, in the state of a carbonate, by carbonate of potash, not added in excess.

By calcining a mixture of bichromate of potash and sulphur in a crucible, a chromic acid is also decomposed, and a hydrated oxide may also be obtained; the sulphur being partly converted into sulphur of potash, and partly into sulphuric acid, (at the expense of the
CHROMIUM, BLUE OXIDE OF.

Chromic acid, which combines with the rest of the potash into a sulphate. By careful lixiviation, these two new compounds may be washed away, and the chrome green may be freed from the remaining sulphur by a slight heat.

Preparation of Green Oxide of Chromium for Calico-printing.—The following directions are given by De Kerr: At the commencement of the process the green hydrate of the oxide of chromium is first prepared by dissolving 4 kilogrammes of bichromate of potash in 22 litres (99 pints) of boiling water. Then into a boiler or vessel containing 108 litres (24 gallons) of boiling water, 4 or 5 kilogrammes (8 or 10 lbs.) of pulverized white arsenic are thrown, and boiled for 10 minutes; a precipitate will be formed, and must be allowed to settle: the clear liquor is then run off, and immediately mixed with the solution of bichromate of potash, stirring all the time: in a short time the mixture acquires a green tint, and the hydrated oxide of chromium will be formed and precipitated. After being several times well stirred, and allowed to cool, the whole is thrown upon a filter of white wool, and the hydrate of chromium remaining on the filter is carefully washed with boiling water. It is then dried, and ready to be employed for the preparation of the chloride. In order to obtain that salt, hydrochloric acid of 22° Beaume is diluted with water, until the acid no longer gives off vapor. It is then heated, and, whilst hot, as much of the hydrated oxide of chromium, prepared as above, is added as will saturate the acid and leave a slight excess of the oxide undissolved. The whole is then left to settle, and the clear liquor is decanted from the dissolved matter. In this state the solution of chloride of chromium still presents some traces of free acid, which would act injuriously upon the fibres of the cotton. To remove this, and to obtain the product in a neutral state, potash lye (marking 36° Beaume) is poured in very gradually, until the oxide of chromium begins to be precipitated.

The solution of chloride of chromium thus prepared, and which is of a dark green color, is evaporated until it marks 46° Beaume; after cooling, oxide of chromium of the finest green color is obtained. This preparation is sold under the name of Sea-green.

This oxide may also be prepared by decomposing, with heat, the chromate of mercury, a salt made by adding to nitrate of protoxide of mercury, chromate of potash, in equivalent proportions. This chromate has a fine chromah red, when pure; and, at a dull red heat, parts with a portion of its oxygen and its mercurial oxide. From M. Delong's experiments it would appear that the purest chromate of mercury is not the best adapted for preparing the oxide of chrome to be used in porcelain painting. He thinks it ought to contain a little oxide of manganese and chromate of potash to afford a green color of a fine tint, especially for pieces that are to receive a powerful heat. Pure oxide of chrome preserves its color well enough in a muffle furnace; but, under a stronger fire, it takes a deal-leaf color.—H. M. N.

CHROMIUM, BLUE OXIDE OF. The following directions have been given for the preparation of a blue oxide of chromium: The concentrated alkaline solution of chromate of potash is to be saturated with weak sulphuric acid, and then to every 8 lbs. is to be added 1 lb. of common salt, and half a pound of concentrated sulphuric acid; the liquid will now acquire a green color. To be certain that the yellow color is totally destroyed, a small quantity of the liquor is to have potash added to it, and filtered; if the fluid is still yellow, a fresh portion of salt and of sulphuric acid is to be added: the fluid is then to be evaporated to dryness, redissolved, and filtered; the oxide of chrome is finally to be precipitated by caustic potash. It will be of a greenish-blue color, and, being washed, must be collected upon a filter.—H. M. N.

CHRYSOBERYL, or GOLDEN BERYL, is composed of alumina 80 2 and glucina 19 8 = 100. It is of various shades of yellowish and light green, sometimes with a bluish opalescence internally. It has a vitreous lustre, and varies from translucent to transparent. Fracture, conchoidal or uneven. Specific gravity = 3.5 to 3.8. It belongs to the triclinic system.

This stone, when transparent, furnishes a beautiful gem of a yellow-green color, which is cut with facets, unless it be opalescent, in which case it is cut as cabochon. It occurs in the Brazilis and Ceylon, in rolled pebbles in the alluvial deposits of rivers; in the Ural, in nica-slate; and at Haddam, Connecticut, U. S., in granite, traversing gneiss.—H. W. B.

CHRYSOLITE, or PERIDOT. The name given to the paler and more transparent crystals of olivine, the latter name being restricted to imbedded masses or grains of inferior color and clearness. It is usually found in angular or rolled pieces, rarely crystallized. The crystals (generally 8, 10, or 12-sided prisms) are variously terminated, and often so compressed as to become almost tubular. They are generally very fragile, and therefore unfit for ornamental purposes. Oriental chrysolite is composed of silica 39-73, magnesin 50-13, protoxide of iron 0-19, alumina 0-22, protoxide of manganese 0-80, oxide of nickel 0-22 = 99-68.—Strossmayer.

As a gem, chrysolite is deficient in hardness and play of color; but when the stones are large and of good color, and well cut and polished, it is made into necklaces, &c., with good effect. From its softness, which is little less than that of glass, it requires to be worn with care, or it will lose its polish. The best mode of displaying the colors to the greatest ad-
vantage is to cut it in small steps. To give it the highest polish, a copper wheel is used, on which a little sulphuric acid is dropped. During the process, a highly supersaturated smell is given out, produced, probably, by the oxidation of the copper and the decomposition of the acid. Chrysolite is supposed to have been the topaz of the ancients. It is found near Constantinople; at Vesuvius; and the Isle of Bourbon, at Real del Monte; in Mexico; in Egypt; and at Expally, in Auvergne.—H. W. B.

CHRYSOPRASE. An apple-green or deep-green variety of chalcedony, the color of which is caused by the presence of nickel. It occurs at Rosenzietz, in Silesia, and Belmont's lead mine, St. Lawrence County, New York.

This stone was probably the chrysobryt of the ancients.—H. W. B.

CINCHONINE. C₁₀H₁₈N₂O₂. An alkaloid isomerie with cinchonine and cinchonidine. It is produced by the action of heat on any of the saline combinations of cinchonine. (Pestier.) To obtain cinchonine, it is only necessary to add a small quantity of water and sulphuric acid to sulphate of cinchonine, and, after driving off all the water at a low temperature, to keep the salt for a few hours at a temperature between 250° and 270°. The product is pure sulphate of cinchonine. By a similar reaction quinine becomes converted into quinoline; quinidine also is susceptible of a similar metamorphosis.—C. G. W.

CINCHONIDINE. C₁₀H₁₈N₂O₂. This alkaloid, the quinidine of Leers, is one of the isomers of cinchonine. There is much confusion to be found in works on the cinchona alkaloids, partly arising from the troublesome system of giving them names greatly resembling each other, and partly from mixtures having been analyzed under the impression of their being pure bases. For some remarks on this subject, see Quinidine. Cinchonidine was first noticed by Wincheler; it is found accompanied by a little quinine in the Cinchona Bogota, of the province of Macarabe. For the reactions of cinchonidine, and its associated bases with chlorine water and ammonia, see Quinine.—C. G. W.

CINCHONINE. C₁₀H₁₈N₂O₂. An alkaloid or organic base accompanying quinine. In consequence of its being considered less fungible than quinine, it is always carefully removed from the latter. Some of the differences of properties on which processes for their separation may be founded are the following: Cinchonine crystallizes more readily than quinine from an alcoholic solution, in consequence of its being less soluble in that fluid. Sulphate of quinine, on the other hand, is less soluble than sulphate of cinchonine. Cinchonine is insoluble, while quinine is freely soluble in ether. Cinchonine forms a great number of salts, which for the most part are well defined, and crystallize readily. It is not so bitter as quinine. In cold water it is quite insoluble, and even when boiling, 2,500 parts are required to dissolve one of cinchonine. Laurent has studied the action of the halogens on it at considerable length, but there are several points connected with this portion of their history which requires re-investigation. Treated with potash at a high temperature, a basic fluid is obtained, formerly considered to be pure cincholine, but which has been shown by the author of this article to contain pyrrol, all the pyridine series, chinoline, and a new base, leptiline.—C. G. W.

CINNABAR, is the principal and only valuable ore of the mercury of commerce, which is prepared from it by sublimation.

It is a sulphide (sulphuret) of mercury, composed, when pure, of quicksilver 86-2, sulphur, 13-8, in which case it is a natural vermilion, and identical with the vermillon of commerce; but it is sometimes rendered impure by an admixture of clay, bitumen, oxide of iron, &c. Cinnabar is of a cochinial red color, often inclining to brownish-red, and lead-gray, with an adamantine lustre, Approaching to metallic in dark varieties, and to dull in friable ones. It varies from sub-transparent to opaque, has a scarlet streak, and breaks with a sub-conchoidal uneven fracture. H = 2 to 2-5, specific gravity = 8-99. In a matrix it entirely sublimes, and with soda yields mercury with the evolution of sulphurous fumes. When crystallized, it belongs to the rhombohedral system.

Cinnabar occurs in beds in slate-rocks. The chief European beds are at Almaden near Cordova, in Spain, and at Idria in Upper Carnithia, where it usually occurs in a massive form, and is worked on a thick vein belonging to the Alpine carboniferous strata. It also occurs abundantly in China, Japan, Fiuana Vilica in South Peru, and at New Almaden in California, in a mountain east of San José, between the Bay of Francisco and Monterey where it is very abundant, and easy of access. The chief source of the mercury used in England is Spain, whence 10 cwt. of cinnabar and 14,514 lbs. were imported in 1857.

Cinnabar in the arts is used as a pigment, in the state of a fine powder, which is known by the name of vermilion. See VERMILION.—H. W. B.

CLOVE OIL. (C₆H₅O₃H₂O₃: Syn. Eugenic acid, Carophylic acid.) When cloves are distilled with water, a large quantity of oil passes over. It has been examined by Dumas, Erding, Böckmann, Stephenson, Calvi, and, more recently, by Greville Williams. Treated with solution of potash, the greater portion dissolves, leaving a small quantity of a hydrocarbon isomerie with oil of turpentine. See CARBURETTED HYDROGEN. The potash solu-
COAL.

The density of its vapor was found to be 5.86. Theory requires 5.67. The above results were confirmed by a determination of the percentage of baryta in the eugenite.

—C. G. W.

COAL. The coal-fields of the United Kingdom are the most important of any worked in the world. Their production has been variously estimated as being between thirty-one and fifty-four millions of tons annually. It has now been determined by inquiries carefully made by the Keeper of Mining Records that these amounts were far exceeded, as is shown by the following returns:

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Northumberland and Durham</td>
<td>15,420,615</td>
<td>15,431,400</td>
<td>15,493,589</td>
</tr>
<tr>
<td>Cumberland</td>
<td>887,000</td>
<td>890,549</td>
<td>915,891</td>
</tr>
<tr>
<td>Yorkshire</td>
<td>7,260,500</td>
<td>7,475,470</td>
<td>9,085,625</td>
</tr>
<tr>
<td>Derbyshire</td>
<td>2,406,696</td>
<td>2,456,000</td>
<td>3,299,225</td>
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<td>Nottinghamshire</td>
<td>813,474</td>
<td>809,400</td>
<td>1,095,000</td>
</tr>
<tr>
<td>Warwickshire</td>
<td>255,000</td>
<td>262,000</td>
<td>355,000</td>
</tr>
<tr>
<td>Leicestershire</td>
<td>459,000</td>
<td>428,000</td>
<td>632,478</td>
</tr>
<tr>
<td>Staffordshire and Worcestershire</td>
<td>7,500,000</td>
<td>7,320,000</td>
<td>7,805,500</td>
</tr>
<tr>
<td>Lancashire</td>
<td>9,080,500</td>
<td>8,950,000</td>
<td>8,950,000</td>
</tr>
<tr>
<td>Cheshire</td>
<td>786,600</td>
<td>755,500</td>
<td>755,327</td>
</tr>
<tr>
<td>Shropshire</td>
<td>1,080,000</td>
<td>1,105,200</td>
<td>752,100</td>
</tr>
<tr>
<td>Gloucester, Somersett and Devon</td>
<td>1,422,466</td>
<td>1,406,620</td>
<td>1,503,000</td>
</tr>
<tr>
<td>Wales</td>
<td>9,643,000</td>
<td>9,577,276</td>
<td>9,665,600</td>
</tr>
<tr>
<td>Scotland</td>
<td>7,448,000</td>
<td>7,325,000</td>
<td>7,390,000</td>
</tr>
<tr>
<td>Ireland</td>
<td>148,750</td>
<td>144,620</td>
<td>136,635</td>
</tr>
</tbody>
</table>

Total of 64,661,401 tons, as reported in 1877.

The total number of collieries in the United Kingdom being

England | 1,948
Wales | 238
Scotland | 405
Ireland | 71

Total of 2,654 collieries.

The distribution of coal in the United Kingdom is one of vast importance to the country. It is spread over large areas, commencing with Devonshire in the south, and extending to the northern divisions of the great Scotch coal-fields. A careful examination of all these deposits cannot but prove useful.

DEVONSHIRE. Lignite of Bovey-Heathfield.—Lysons (Magna Britannia) informs us that this so-called Bovey coal was worked for use early in the last century; and Dr. Maton described those beds in 1797 as being from 4 to 16 feet in thickness, alternating with clay, and he stated that the pits were about 80 feet deep, and worked for the supply of a neighboring pottery. A pottery was established at Ideo in 1772, and one at Bovey Tracey in 1812, both of which were supplied with fuel from those lignite beds. Those beds are supposed to have been formed towards the latter part of the supercretaceous periods. The wood of which they are formed has been sometimes supposed to be analogous to the oak and other existing trees. The offensive smell emitted by this lignite when burnt has always prevented its use for domestic purposes, except among the poorer cottages of the neighborhood. The supply from those beds of "Bovey coal" is now falling off, the adjoining pottery being compelled to use some coal as fuel.—De la Beche.

BIDFORD Anthracite.—The beds of Anthracite stretch across the country from Barnstable Bay, by Bideford and Averdisco, towards Chittlehampton, a distance of about
twelve miles and a half. The anthracite is mixed with the black shales of the carbonaceous deposits.

"The anthracite is mixed with those shales in the manner represented beneath, fig. 160; a, sandstones; b, shales; c, culm or anthracite; so that the culm itself seems the result of irregular accumulations of vegetable matter intermingled with mud and sand. As so frequently happens with carbonaceous deposits of this kind, nodules of argillaceous ironstones are often found in the same localities with the shales and anthracite, reminding us of the intermixture of iron ores and vegetables matters in the bogs and morasses of the present day."—De la Beche.

SOMERSETSHIRE AND GLOUCESTERSHIRE.—The Dean Forest coal-field, and the coal measures, extending further south forming the Bristol coal-field, are included in this division. The workable seams of coal in the forest are the following:—

<table>
<thead>
<tr>
<th>Seam Name</th>
<th>(having a thickness of)</th>
<th>ft.</th>
<th>in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dog Delf</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Smith Coal</td>
<td></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Little Delf</td>
<td></td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Park End High Delf</td>
<td></td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Stakley Delf</td>
<td></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Little Coal</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rocky Delf</td>
<td></td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Upper Churchway Delf</td>
<td></td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Lower Churchway Delf</td>
<td></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Braizley Delf</td>
<td></td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Nag’s Head, or Weaver’s</td>
<td></td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Whittington Delf</td>
<td></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Coleford High Delf</td>
<td></td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Upper Trenchard</td>
<td></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Lower Trenchard</td>
<td></td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

There is a small coal-field north of the Forest of Dean, which is a long narrow strip, containing two and a half square miles, or 1,600 acres.—Murchison, Geological Transactions, vol. v.

About nine miles and a half to the south of Dean Forest a considerable mass of coal measures has been preserved from destruction, by the demuding causes which have carried off the connecting portion between it and Dean Forest, leaving at least two outlying patches on the north of Chepstow.

The Bristol coal-field occupies about fifty square miles, or 32,000 acres. The seams of coal are very thin in comparison with those which are worked in other districts. Buckland and Coneybeare (Geological Transactions, vol. i.) have well described this coal-field.

The total thickness of the whole series of strata in this Bristol coal-field has been shown by De la Beche to be as follows:—

- Upper shales and limestones 1,800 feet, with 10 beds of coal.
- Middle sandstone 1,725 feet, with 5 beds of coal.
- Lower shales 1,565 feet, with 36 beds of coal.
- Farewell Rock 1,200 feet.

6,290

SOUTH WALES COAL FIELD.—The total thickness of the coal strata in this important district is very great. Logan and De la Beche have accumulated evidence which appears to justify the admission of 11,000, or even 12,000 feet thickness from the carboniferous limestone to the highest part of the coal series about Llanelly; in other parts of the field the series is found to be of proportions only less gigantic. The most general view which can be afforded seems thus, giving the true coal measure about 8,000 feet:—

- Llanelly series, with several beds of coal 1,000 feet.
- Penllergare series of shales, sandstones, and beds of coal, 110 beds; 26 beds of coal 3,000 feet.
Central series. (Townhill sandstones of Swanse, Pennant grit of the
Bristol field:) 62 beds, and 16 beds of coal—3,246.
Lower shales, coals, and iron-stones, (Merthyr:) 266 beds, 34 beds of
coal—812.
Abundance of iron-stone beds and unionized occur.
Parewell-Rock and Gower shales above; the carboniferous limestone below.

The coal on the north-eastern side of the basin is of a coking quality, excellent for the
iron manufacture; on the north-western it contains little or no bitumen, being what is
called stone-coal or anthracite; on the south side, from Pontypool to Caermarethen Bay, it
is of a bituminous or binding quality.—Phillips.

SHROPSHIRE. This district includes the small coal-field of Coalbrook Dale, and that of
the plain of Shrewsbury. The Coalbrook Dale field, according to Mr. Prestwick, has some
remarkable features. (Geological Transactions.) Perhaps there is no coal track known,
which in so small a compass, about twelve miles long, and, at most, three and a half miles
wide, exhibits so many curvatures in the outcrops, crossed by so many continuous faults,
some varying north by east, others cast-north-east; these crossed by many of shorter
length, and directed west-north-west, and in several other lines. The total thickness is
supposed to be 1,000 or 1,100 feet, divided into 80 distinct strata. The coal varies in total
thickness from 16 feet to 55, and in the number of its beds from 7 to 22, the increase being
to the north. The "cleat" or systems of joints run from west-north-west to east-south
east. The coal, for the most part, of the variety called slate coal in Scotland, and hard
c coal in Derbyshire. Cannel coal is rare—sulphureous coal (pyritic) very common. Pe-
troleum abounds in the central and upper part of the field. The beds are mostly thin; the
ten uppermost are too sulphureous for other uses than lime-burning, and are called stinkers;
twelve beds of good coal, in all 25 feet thick, the thickest being five feet, succeed, and the
lowest bed of the whole formation, eight inches thick, is sulphureous.—Phillips, Prestwick.

STAFFORDSHIRE. The coal-field of South Staffordshire, which has been described by
Mr. J. Beetie Jukes, who states its boundary would be roughly described as the space in-
cluded within a boundary line drawn from Rugeley through Wolverhampton to Stourbridge;
hence to the southern end of the Bromsgrove Lickey, and returning through Harborne
(near Birmingham) and Great Barr back to Rugeley. This geologist classes these coal strata
in three divisions, by the well-traced band of thick coal. The total thickness of coal near
Dudley being about 57 feet, and between Bilston and Wolverhampton upwards of 70 feet.
The thick coal is formed of eight, ten, or thirteen distinguishable parts, the whole seam
varying in thickness from three feet to thirty-nine feet five inches; it is very irregular in
parts, divided by sandstone, splitting with wide-shaped offshoots, and cut into "swivels" or
"horse backs," which rise up from the floor. Below the thick coal are numerous beds of
sandstone-slates, coal, and iron-stone, having on the average a thickness of 520 feet; and
above the thick coal the thickness is 250 feet on the average.—Records of the School of
Mines.

North Staffordshire Coal-field. This field is comprised in the space between Congleton,
Newcastle-under-Lyme, and Lame End. About 32 beds of coal have been determined, rising
castward between Burelem in the centre of the field and its eastern limit near Norton
church.

DERBYSHIRE AND NOTTINGHAMSHIRE. The Derbyshire and Nottinghamshire coals are
classed as to structure in two varieties, as "hard" coal, in which the divisional structures
are chiefly derived from the planes of stratification, crossed by one set of "cleat" or
natural joints, (called "slices," "backs," &c.) so that large prismatic masses result; "soft"
c coal, where the cleat fissures are numerous, and broken by cross cleat. In respect of the
quality, some of the coal is of a "crozing" or coking nature, easily fusible, and changing
its figure by "cokeing" the rest, and (this is specially the case with the "hard" variety)
makes both good furnace coal and excellent coke, which, however, is hardly melted at all,
and the masses are not changed in figure by the process.—Phillip's Manual of Geology.

The names by which the more important beds of coal worked within this district are
known, are as follows: Tupton coal, hard coal, soft coal, black shale or clod coal, low hard
coal and low soft, windmill coal, Dunall coal, Gannister coal, Parkgate coal, Aston coal, Kil-
burn coal, Furnace coal, Hazel coal, Eveska coal, main and deep coal.

LEICESTERSHIRE AND Warwickshire. The Leicesterser coal-field is best developed about
Ashby de la Zouch, (see Mammoth on "the coal-field of Ashby de la Zouch") where the
c coal is much like the hard coal of Derbyshire. Amongst the seams of coal is one variety
called cannel; and another, formed by the concussion of more than one bed, from seven-
teen to twenty-one feet in thickness. The beds near Ashby de la Zouch are as follows:—

In the Moira district—
### Coal

<table>
<thead>
<tr>
<th>Coals</th>
<th>Thickness of beds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eureka coal</td>
<td>4 to 6 feet.</td>
</tr>
<tr>
<td>Stocking coal</td>
<td>6 to 7 ft.</td>
</tr>
<tr>
<td>Woodfield coal</td>
<td>5 ft.</td>
</tr>
<tr>
<td>Slate coal</td>
<td>3½ to 4 ft.</td>
</tr>
<tr>
<td>Nether main coal</td>
<td>14 to 15 ft.</td>
</tr>
<tr>
<td>Fourfoot coal</td>
<td>4 to 5 ft.</td>
</tr>
<tr>
<td>The Earl coal</td>
<td>4 ft. 6 in.</td>
</tr>
</tbody>
</table>

In the Coleorton district—

- Heath End coal - 2 feet.
- Lount coal - (3 beds.)
- Main coal - 10 to 12 feet.

**The Warwickshire Coal-field** is from a point east of Tamworth to a point east of Coventry, about twenty miles from N. W. to S. E. parallel to the Ashby coal tracts. The strata are most productive of coal near the southern extremity, where by the coming together of two seams,—worked separately at Grift,—the five-yard seam is worked. The beds are known as the seven-feet coal and rider, slate coal, two yards, lower seam, eannel, and Ill coal.

**Yorkshire.**—Professor John Phillips gives the following mode of classification as the most natural and convenient for the Yorkshire coal.

Magnesian limestone unconformably covers the coal seams.

**Upper coals**

- Shales and Badsworth coal.
- Ackworth rock.
- Wragby and Sharlston coals.

**Red rock of Wooley** Hooton-Roberts, &c.

- Furnace coals. - Barley thick coal.
- Rock of Horbury.
- Intermediate coals. - Middle coals.
- Iron-stone coals. - Silkstone and Flockton beds.
- Low Moor coals.

**Flagstone rock of Woodhouse, Bradford, Elland, Peniston, &c.**

- Shales and ganister stone.
- Coals.

**Lower coals**

- Shales and ganister stone.
- Coals.
- Shales, &c.

**Millstone grit lies below the “coal series.”**

The important middle coal series are again divided by Professor Phillips as follows:—

- Red rock of Wooley Edge.
- Furnace coals of Barley, &c., including the eight or ten feet seam.
- Rock of Horbury and Wentworth House.
- Swift burning coals of Middleton, Dewsbury, &c., with bands of *mussels*.
- Biruminous coals of Silkstone and Low Moor.
- Flagstone rocks beneath.

The small coal-field of Ingleton and Black Burton in Lonsdale is thrown down on the south side of the great Craven fault.

**Lancashire.**—The coal-field of Lancashire occupies an area extending from Macclesfield to Châne, 40 miles, and from Torboch, near Liverpool, to Todmorden, about 40 miles. Excluding the millstone grit, its area is about 250 square miles.—Heigwood.

In a line through Worsley, Burn, and Burnley to the limestone shales of Pendle Hill, we have 38 seams of coal, 10 of them not exceeding 1 foot in thickness, making in all 93 feet of coal.

The series is divided into three parts above the millstone grit:

- **Upper part**, containing a bed of limestone at Ardwick near Manchester.
- **Middle part**, containing the greater part of the thick and valuable seams, especially the eannel coals of Wigan.
- **Lower part**, corresponding to the ganister series of Yorkshire.

**Cheshire.**—The coal-field of Cheshire is not of great importance.

**North Wales.**—*Flintshire and Denbighshire.*—The Flintshire coal basin extends from north to south, somewhat more than 30 miles from Llanasa to near Oswestry in Shropshire. The coal strata dip generally eastward and form in the northern part a trough beneath the estuary of the Dee. This coal basin in Flintshire commences with beds of shale and sandstone. The coal is of various thickness, from ½ to 5 yards, and consists of the common, eannel, and peacock varieties.—Phillips and Conybeare.
COAL.

Cumberland.—This coal-field extends as a narrow crescent from Whitehaven to near Hesket Newmarket:—around Whitehaven and at Workington the coal is worked extensively. At the latter place, a few years since, a very valuable colliery was destroyed by the bursting of a seam.

There are three workable seams in the Cumberland coal-field in the neighborhood of the three undermentioned towns, and these are known in each place by the names given:—

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Main band.</td>
<td>Main seam.</td>
<td>Caused and metal seams, (divided with shale from 2 feet to 5 fathoms thick.)</td>
</tr>
<tr>
<td>Six-quarter coal or Low-bottom seam.</td>
<td>Hamilton seam.</td>
<td></td>
</tr>
</tbody>
</table>

Northumberland and Durham.—The total thickness of the coal measures of this district is about 1,600 feet. The number of distinct layers or beds, as usually noted by the miners, about 600. The total thickness of the beds of coal rarely exceeds—does not, on the average, equal—60 feet. No bed of coal is of greater thickness, even for a short distance, than 6 or 7 feet; several are so thin as to be of no value at present. The total thickness of "workable coal," supposing all the beds to be found in a given tract, is not to be estimated at above 20 or 30 feet. The most part of the coal in this great district is of the coking quality, but, in this respect, there is much variation. The best coke for locomotive engines is now made from the lower coals in the Auckland district of Durham, and the Shildon Bridge district of Northumberland. The best "steam coal" is obtained from the north side of the Tyne and the Blyth district. The best "house coal" still comes from the remains of the "High chain" on the Tyne, and from the "Hutton seam" on the Wear; but the collieries north of the Tees have acquired a high reputation.

As a general view of the groups of strata the following summaries may suffice.—(Foster and Biddle.)

Upper groups of coal measures, including chiefly thin seams of small value (8 or more) in a vast mass of sandstone and shale, with some iron-stone. At the base is a muskel band; we estimate this at 900 feet.

**On the Tyne:**

<table>
<thead>
<tr>
<th>Middle group</th>
<th>Ft.</th>
<th>In.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High main coal</td>
<td>-</td>
<td>6 0</td>
</tr>
<tr>
<td>Strata and thin coals</td>
<td>-</td>
<td>60 0</td>
</tr>
<tr>
<td>Metal coal</td>
<td>-</td>
<td>1 6</td>
</tr>
<tr>
<td>Strata and thin coals</td>
<td>-</td>
<td>3 0</td>
</tr>
<tr>
<td>Stone coal</td>
<td>-</td>
<td>83 0</td>
</tr>
<tr>
<td>Strata</td>
<td>-</td>
<td>3 0</td>
</tr>
<tr>
<td>Yard coal</td>
<td>-</td>
<td>90 0</td>
</tr>
<tr>
<td>Bedham seam</td>
<td>-</td>
<td>3 0</td>
</tr>
<tr>
<td>Strata with several variable beds and some layers of mussels</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Low main coal</td>
<td>-</td>
<td>6 0</td>
</tr>
<tr>
<td>Strata</td>
<td>-</td>
<td>200 0</td>
</tr>
<tr>
<td>Hervey's seam</td>
<td>-</td>
<td>3 0</td>
</tr>
<tr>
<td>Strata</td>
<td>-</td>
<td>300 0</td>
</tr>
<tr>
<td>Brockwell seam</td>
<td>-</td>
<td>3 0</td>
</tr>
<tr>
<td>Strata above millstone grit</td>
<td>-</td>
<td>200 0</td>
</tr>
</tbody>
</table>

**On the Wear and Tyne:**

<table>
<thead>
<tr>
<th>Ft.</th>
<th>In.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five-quarter coal</td>
<td>3 9 to 6 9</td>
</tr>
<tr>
<td>Main coal</td>
<td>5 6 to 6 0</td>
</tr>
<tr>
<td>Mandlin seam</td>
<td>4 6 to 6 0</td>
</tr>
<tr>
<td>Low main or Hutton seam</td>
<td>6 4 to 6 6</td>
</tr>
<tr>
<td>Beaumont seam</td>
<td>3 0 to 6 0</td>
</tr>
<tr>
<td>Brockwell seam</td>
<td>3 0 to 6 0</td>
</tr>
</tbody>
</table>

The seams which are principally worked in this district are the high main, five-quarter main, Bedham seam, Hutton seam, Beaumont seam, low five-quarter, three-quarter seam, Brockwell and stone coals. These seams are known by other names, each district usually adopting its own peculiar term to designate the workable seams. Thus the Bedham seam of the Tyne is known as the Mandlin seam of the Wear. The Beaumont or Hervey seam is the Townley seam of the Townley colliery and the main coal of Wyham colliery. At Hetton the high main seam of the Cramlington district separates into two, and is called the three-quarter seam at Ponton:—where it unites again it is known as the Shieldrow seam. The Cramlington gray seam is the metal-coat seam and stone coal seam of Sherriff Hill, where it is divided; while it unites at Hetton and forms the five-quarter seam of that and the Auckland district. The Cramlington yard seam becomes the main coal seam at Hetton, Haswell, and some other localities, the Brass Thall at Ponton, and the main coal in Auckland. Again the Cramlington five-quarter seam divides and forms the six-quarter, and the five-quarter at Sherriff Hill the Brass Thall seam at Pittington; they again unite and form
the Hutton seam at Pontass colliery, and so with regard to a few others.—*Mineral Statistics.*

**SCOTLAND.**—"A memoir on the Mid-Lothian and East Lothian coal-fields," by David Milne, gives the most exact account of the carboniferous system of Scotland.

There are three principal coal basins in Scotland: 1. that of Ayrshire; 2. that of Clydesdale; and 3. that of the valley of the Forth, which runs into the second in the line of the Union canals. If two lines be drawn, one from Saint Andrews on the north-east coast, to Kilpatrick on the Clyde, and another from Aberlady, in Haddingtonshire, to a point a few miles south of Kirkoswald in Ayrshire, they will include between them the whole space where pitcoal has been discovered and worked in Scotland.

According to Mr. Farey, there are 337 principal alterations of strata between the surface in the town of Fisherrow, on the banks of the Frith of Forth, (where the highest of these strata occur,) and the commencement of the basaltic rocks, forning the general floor and border of this important coal-field. These strata lie internally in the form of a lengthened basin or trough, and consist of sandstone, shale, coal, limestone, ironstone, &c. Sixty-two seams of coal, counting the double seams as one; 7 limestone; 72 assemblages of stone and other strata; in all 5,000 feet in thickness.

Professor Phillips remarks of this district, "On the whole, allowing for waste unattainable portions, and other circumstances, this one district may be admitted as likely to yield to the miner for actual use 2,250 millions of tons of coal." The coal is partly "split," partly "rough" or "cherry," partly of the "cannel" or "parrot" variety; the first containing most oxygen, the last, most hydrogen and nitrogen, and the least carbon. See Boghead Coal.

**IRELAND.**—The coal-fields of Ireland, if we include in this term the millstone grit, occupy large tracts of land in that country, and are upon the whole analogous, in general mineral character and organic contents, to those of England. The same absence of limestone, the same kind of succession of sandstones and shales is remarked in them. Anthracite or stone-coal like that of South Wales abounds in the Leinster and Munster districts; bituminous coal occurs in Connaught and Ulster. In Ulster the principal collieries are at Coal Island and Dungannon. The Munster coal district is stated by Mr. Griffith to be of greater extent than any English coal-field, but it is much less productive. At Ballycastle the coal is found in connection with basalt.—*Phillips.*

Such a general and rapid sketch of the distribution of fossil fuel over the Islands of the United Kingdom. The importance of a correct knowledge of the distribution of coal in other parts of the world, especially to a commercial people whose steamers now traverse every sea, has led to the compilation, from the most reliable sources, of the following account:

Between the Arctic Circle and the Tropic of Cancer repose all the principal carboniferous formations of our planet. Some detached coal deposits, it is true, exist above and below these limits, but they appear, so far as we know, to be of limited extent. Many of these southern coal-fields are of doubtful geological age; a few are supposed to approximate to the class of true coals, as they are commonly styled, others are decidedly of the brown coal and tertiary period, while the remainder belong to various intermediate ages, or possess peculiarities which render them of doubtful character.

Southward of the Tropic of Cancer the existence of coal corresponding with the European and American hard coal is somewhat uncertain. There seems to be little coal on the South American continent. The discovery said to be made at Ano Paser needs confirmation, and of that in the province of Santa Catharina in Brazil we know little. On the African continent we have had vague accounts of coal in Ethiopia, and at Mozambique, also at Madagascar, and quite recently we have had intelligence of large quantities of coal in the newly ceded territory above Port Natal, on the eastern side of Africa, but we believe no geologist has examined these sites. In the Chinese and Burmese empires brown coal only appears to approach the Tropic, but true coal seems to exist in the northern provinces. Southward of the Asiatic continent we are uncertain of the exact character of the coal deposits, such as occur at Sumatra, Java, and Borneo, and neighboring islands. Coal, however, exists in these islands, and is of a fair workable quality.

In New South Wales the great coal range on the eastern margin of that continent has sometimes been described as resembling the Newcastle coal in England, and sometimes it is described as of more ancient date. This coal differs essentially from that of any known European formation, but bears a strong resemblance to the Burdwan coal of India.

We have not yet arrived at the period when we could pronounce with any approach to certainty on the actual number of coal basins in the world; the total number must, however, amount at least to from 200 to 300 principal coal-fields, and many of these are subdivided by the disturbed position of the strata into subordinate basins.

The basins or coal districts are, however, grouped into a comparatively small number of districts, and even many of these are little known and not at all measured. The greater
COAL.

number occur in Western Europe and Eastern North America, while Central and Southern Africa, South America, and a large part of Asia are almost without any traces of true carboniferous rocks. The remarks, therefore, that will follow chiefly refer to our own and adjacent countries, or of the United States and British North America.

The principal coal-fields of Europe, apart from the British Islands, are those of Belgium, France, Spain, (in the Asturias,) Germany, (on the Ruhr and Saar,) Bohemia, Silesia, and Russia, (on the Donetz.)

BELGIUM.—The Belgian coal-field is the most important, and occupies two districts, that of Liège and that of Hainault, the former containing 100,000, and the latter 260,000 acres. In each, the number of coal seams is very considerable, but the beds are thin and so much disturbed as to require special modes of working. The quality of coal is very various, including one peculiar kind, the Flenu coal, unlike any found in Great Britain, except at Swansea. It burns rapidly with much flame and smoke, not giving out an intense heat, and having a somewhat disagreeable smell. There are nearly fifty seams of this coal in the Mons district. No iron has been found with the coal of Belgium.

Mr. Dunn, H. M. Inspector of Collieries, has reported on the coal of Belgium: and first quoting a report which announces that the mines would be exhausted in twenty years, says: "This announcement comes with appalling force upon the numerous joint-stock companies.

* * * According to the report of M. Briquiois, Belgium is traversing towards a momentous crisis; and I am much inclined to confirm the writer’s opinion that, according to the present plan of working on the collieries, notwithstanding the high price received for the coal, yet that coal will not be found workable to profit below the depth of 250 or 260 fathoms, inasmuch as the deeper they go the more destructive and unmanageable will be the effects of the pressure."—The Government Mining-Engineer’s Report.

Belgium is traversed, in a direction from nearly west-south-west to east-north-east, by a large zone of bituminous coal formation. The entire region is generally described under two principal divisions:—

1. The western or Hainault division, comprising
   a. The two basins known as Levant and Couchant of Mons.
      That of Charleroi.
   b. The basin of Namur.

2. The eastern or Liège division.

FRANCE.—The most important coal-fields of France are those of the basin of Loire, and those of St. Etienne, which are the best known and largest, comprising about 50,000 acres. In this basin are eighteen beds of bituminous coal, and in the immediate neighborhood several smaller basins containing anthracite. Other valuable localities are in Alsace, several in Burgundy worked by very deep pits, and of considerable extent; some in Auvignes with coal of various qualities; some in Languedoc and Provence with good coal; others at Arveyron; others at Limosin; and some in Normandy. Besides these, there are several others of smaller dimensions and less extent, whose resources have not been developed. The total area of coal in France has not been ascertained, but it is probably not less than 2,000 square miles. The annual production now exceeds 4,000,000 tons. But the coal of France is of an inferior description, and, therefore, when good and strong coals are required, the supply is obtained from the English coal-fields. The mineral combustibles of France are divided by the government engineers into

| Anthracite, not yielding coke. | Gaseous coal, long flame. |
| Hard coal, short flame.       | Small coal, long flame.  |
| Forging or gaseous coal.      | Lignite, Stipite, &c.    |

The total of indigenous fuel extracted, according to the State returns, is 47,222,743 metrical quintals of 101453 to the English ton.

The geological phenomena attendant upon the coal formations in France are, that in some places we have the coals resting on the granite and schists, and in others on the Silurian rocks.

Taylor gives the details of eighty-eight coal, anthracite, and lignite basins in France. In 1852 only nine of these produced coal to any extent. The total produce of all the coal-fields being 4,818,555 tons, valued at £1,870,072 sterling.

GERMANY.—The Germanic Union—the Zollverein—embraces the following principal coal-beds—

| German States. | Saxony. |
|               | Bavaria. |
|               | Duchy of Cleves. |
|               | La Ruhr, in Westphalia. |
|               | Silesia. |
|               | Saarbrück, and provinces of the Bas Rhin. |
The true coal of Prussian Silesia stretches for a distance of seventeen leagues. The most recent information we have been able to obtain as to its production, would appear to give above 850,000 English tons. The coal-fields of Westphalia were described by Sedgwick and Murchison in 1840. The productive coal-beds are on the right bank of the Rhine, and possess many features in common with the English coal-fields. Bituminous wood, and lignite or brown coal, occur extensively in some districts. The coal basin of Saarbrück, a Rhenish province belonging to Prussia, has thus been described by Humboldt, chiefly from a communication received from M. Von Dechen:

"The depth of the coal measures at Mont St. Gilles, Liège, I have estimated at 3,650 feet below the surface, and 3,250 feet below the sea level. The coal basin at Mons lies fully 1,750 feet deeper. These depressions, however, are trifling when compared with that of the coal strata of the Saar rivers, (Saarbrück.) After repeated trials I have found that the lowest coal strata known in the county of Duttweiler, near Bettingen, north-eastward from Saar-louis, dip 19,406 feet, and 20,636 under the level of the sea."

The coal of the valley of the Glose is bituminous, and of good quality; it is procurable at a depth of 112 feet, and the seam is about two feet in thickness: about 50,000 tons annually are produced from this valley. Coal is found in Wurtzburg, but not much worked. In Saxony are extensive mines of bituminous coal; at Schönfeld, near Zwickau, the coal alternates with porphyry. Near Dresden a bituminous coal is also worked, and the coke manufactured from it is used in the metallurgical works at Freiburg.

The Russian States produce little beyond lignite. In Hesse Cassel some bituminous coal is worked, but to a very inconsiderable extent.

In the Thuringenwald or Thuringian forest some coal is produced.

HUNGARY and other countries in the east of Europe contain true coal measures of the carboniferous period; but the resources of these districts are not at present developed.

On the banks of the Donetz, in Russia, coal is worked to some extent, and is of excellent quality.

AUSTRIA.—Coal occurs in Styria, Carinthia, Dalmatia, the Tyrol, Moravia, Lombardy, and Venice; but 700,000 tons appear to be the maximum annual produce of the empire. The basin of Vienna, in Lower Austria, produces several varieties of coal, which belong to the brown coal of the tertiary period.

Bohemia.—In this kingdom coals are abundant; one coal-field occupies a length of 15 leagues, and a breadth of from 4 to 5 leagues. Between 300,000 and 400,000 tons are produced annually.

SWEDEN.—anthracite is found in small quantities at Dannemora; and bituminous coal is worked at Helsingborg, at the entrance of the Baltic.

DENMARK.—The island of Bornholm and some other islands belonging to Denmark produce coal, but it would appear to belong to the Bovey coal variety.

RUSIA.—The Donetz coal-field is the most important. In that extensive district many good seams, according to Sir R. I. Murchison, of both bituminous and anthracite coal exist.

TURKEY.—Coal is found bordering on the Carpathian mountains, in Servia, Roumelia, and Bulgaria.

The coal of Heredia, on the south coast of the Black Sea, in Anatolia, has been, since the Crimean war, exciting much attention.

SPAIN.—Spain contains a large quantity of coal, both bituminous and anthracite. The richest beds are in Asturias, and the measures are so broken and altered as to be worked by almost vertical shafts through the beds themselves. In one place upwards of 11 distinct seams have been worked, the thickest of which is nearly 14 feet. The exact area is not known, but it has been estimated by a French engineer that about 12,000,000 of tons might be readily extracted from one property, without touching the portion existing at great depths. In several parts of the province the coal is now worked, and the measures seem to resemble those of the coal districts generally. The whole coal area is said to be the largest in Europe, presenting upwards of 100 workable seams, varying from 3 to 12 feet in thickness.

The Asturias Mining Company are working many mines in this region, and they are said to produce 400,000 tons annually, or to be capable of doing so. In Catalonia and in the Basque provinces of Biscay there are found anthracite and bituminous coals.

In the Balearic islands also coal exists.

PORTUGAL.—Beds of lignite and some anthracite are known to exist, but the production of either is small.

ITALY.—The principal coal mines of Italy are in Savoy and near Genoa. In the Apennines some coal is found, and in the valley of the Po are large deposits of good lignite and a small quantity of good coal is worked in Sardinia.

NORTH AMERICA.—There are in North America four principal coal areas, compared with which the richest deposits of other countries are comparatively insignificant. These are the great central coal-fields of the Alleghenies; the coal-fields of Illinois, and the basin of the
COAL.

Ohio; that of the basin of the Missouri; and those of Nova Scotia, New Brunswick, and Cape Breton. Besides, there are many smaller coal areas which, in other countries, might well take rank as of vast national importance, and which even in North America will one day contribute greatly to the riches of various States.

The Alleghany or Appalachian coal-field measures 750 miles in length, with a mean breadth of 85 miles, and traverses eight of the principal States in the American Union. Its whole area is estimated at not less than 65,000 square miles, or upwards of 40,000 square acres. The coal is bituminous, and used for gas.

Coal has been found in Louisiana, on the Iberville rivers, and on the shores of Lake Bistineau; it is also reported as having been found at Lake Providence. It appears to be at least 6 feet of coal. The Maryland district is less extensive, but is remarkable as containing the best and most useful coal, which is worked now to some extent at Frostbury. There appear to be about 30 feet of good coal in 4 seams, besides many others of less importance. The quality is intermediate between bituminous and anthracite, and is considered well adapted for iron-making. Lastly, in Pennsylvania there are generally from two to five workable beds, yielding on an average 10 feet of workable coal, and amongst them is one bed traceable for no less than 450 miles, consisting of bituminous coal, its thickness being from 12 to 14 feet on the south-eastern border, but gradually diminishing to 5 or 6 feet. Besides the bituminous coal there are in Pennsylvania the largest anthracite deposits in the States, occupying as much as 250,000 acres, and divided into three principal districts.

The Illinois coal-field, in the plain of the Mississippi, is only second in importance to the vast area already described. There are four principal divisions traceable, of which the first, or Indian district, contains several seams of bituminous coal, distributed over an area of nearly 8,000 square miles. It is of excellent quality for many purposes; one kind burning with much light and very freely, approaching cannel coal in some of its properties; other kinds consist of caking or splint coal. In addition to the Indian coal-field there appears to be as much as 48,000 square miles of coal area in other divisions of the Illinois district, although these are less known and not at present much worked. 30,000 are in the State of Illinois, which supplies coal of excellent quality, and with great facility. The coal is generally bituminous.

The third great coal area of the United States is that of the Missouri, which is little known at present, although certainly of great importance.

Taylor states that at least one-eighth of the State of Missouri is overlaid by coal measures. 6,000 square miles are assigned to the coal-fields of Missouri. Bituminous coal is stated to have been found in the Arkansas valley, and brown coal and lignite in abundance in the Upper Missouri valley.

British America contains coal in the provinces of New Brunswick and Nova Scotia. The former presents 3 coal-fields, occupying in all no less than 8,000 square miles; the latter exhibits several very distinct localities where the coal abounds. The New Brunswick coal measures include not only shales and sandstones, as is usual with such deposits, but bands of lignite impregnated with various copper ores, and coated by green carbonate of copper. The coal is generally in thin seams lying horizontally. It is chiefly or entirely bituminous.

Nova Scotia possesses three coal regions, of which the northern presents a total thickness of no less than 14,570 feet of measures, having 70 seams, whose aggregate magnitude is only 44 feet, the thickest beds being less than 4 feet. The Picton or central district has a thickness of 7,350 feet of strata, but the coal is far more abundant, one seam measuring nearly 30 feet; and part of the coal being of excellent quality and adapted for steam purposes. The southern area is of less importance. Besides the Nova Scotia coal-fields there are three others at Cape Breton, yielding different kinds of coal, of which one, the Sydney coal, is admirably adapted for domestic purposes. There are here 14 seams above 3 feet thick, one being 11, and one 9 feet.

Newfoundland Coal-field.—This field is estimated at about 5,000 square miles. According to Mr. Jukes, now Director of the Geological Survey in Ireland, the entire western side of the island, along a space of 356 miles in breadth, is occupied by secondary and carboniferous rocks. The coal on the southwestern point of the island has been traced at intervals, along a space of 160 to 200 miles to the north-east.

Greenland.—Captain Scoresby discovered a regular coal formation here. At Hasen Island, Bovey or brown coal has been found, and also at Disko Island on the western coast.
COAL.

ARCTIC OCEAN.—At Byam Martin’s Island coal formations exist; and at Melville Island several varieties of coal have been discovered, much of it being of an anthracitic or of a semi-anthracitic character. We learn that at Prince Regent’s Inlet indications of coal have been observed.

RUSSIAN AMERICA.—Beyond the icy cape and at Point Barrow, coal was observed on the beach; and it has been found by digging but a few feet below the surface at Point Franklin.

OREGON TERRITORY.—Coal has been discovered and worked in Willamette valley, nearly 100 miles above Oregon City; and anthracite has been observed by Sir George Simpson about 30 miles up one of the tributaries of the Columbia River.

CALIFORNIA.—Colonel Fremont states that a coal formation exists in Upper California, North lat. 41°, and West long. 107°. “The position of this coal formation is in the centre of the Rocky Mountain chain, and its elevation is 6,826 feet above the level of the sea. In some of the coal seams the coal did not appear to be perfectly mineralized, and in others it was compact and remarkably lustrous.”—Fremont’s Report, 1843.

In 1847 a coal mine was discovered near San Luis Obispo, North lat. 35°. There are three coal mines within 20 miles of Monterey.

MEXICO.—On Salado River coal is worked by an American company. A coal formation 50 miles in breadth crosses the Rio Grande from Texas into Mexico at Loredo, and on the Mexican shore, within 200 yards of the Rio Grande, a remarkable fine vein of coal 8 feet thick occurs.

TEXAS.—Coal is known to exist in Texas, though the country has not been geologically examined. The “Trinity Coal and Mining Company” was incorporated by the Texas Congress in 1840, who worked both anthracite and a semi-bituminous coal. Kennedy, in his work, “Texas, its Geography, etc.,” says, “Coal, both anthracite and bituminous, abounds from the Trinity River to the Rio Grande.”

SOUTH AMERICA.—In the republic of New Granada, especially at Santa Fé de Bogota, coal occurs; also in the Island of Santa Clara, and brown coal in the province of Panama.

VENEZUELA is said to contain coal, but whether brown or bituminous coal does not appear certain.

PERU appears to possess some coal, but a fossil charcoal of considerable value is more abundant.

CHILE.—The coal of this district has been examined by many American engineers, and by Captains Fitzroy and Beechey and Mr. Darwin. In 1844 upward of 20 coal mines were opened in the neighborhood of Concepcion. At Tuleahamo a new seam of 43 feet was proved. The coal is described by W. R. Johnson as “in external appearance nearly related to many of the richest bituminous coals of America and Europe;” and Mr. Wheelwright, in his report on the mines and coal of Chili, says, “in fact, the whole southern country is nothing but a mine of coal.”

BRAZIL does not appear to possess much coal of any value, beyond a few lignites.

THE WEST INDIAN ISLANDS.—Cuba, in the vicinity of Havana, produces a kind of asphaltum much resembling coal, the analysis of which gives, carbon 34.97, volatile matter 63.00, ashes 2.08. At New Havana a similar combustible is found; but it contains 71.84 of carbon. True coal does not appear to have been found in Jamaica. Sir H. de la Beche, Trans. Geological Society of London, describes three or four thin seams of coal imbedded in slate near the north-eastern extremity of the island.

BARBADOS.—Bitumen is found plentifully; and, on Grove Plantation estate, a good coal is stated to have been found.

TRINIDAD.—The pitch lake of this island is well known. Near it, and, it is believed, extending under it, a true coal of superior quality is worked.

For a very satisfactory description of the coal-field of South Staffordshire, the reader is referred to a memoir “On the Geology of the Staffordshire Coal-field,” by J. Recte Jukes, published in the “Records of the School of Mines.”

It is not possible in the present work to enter into any further description of the coal-fields of this country. In the selections which have been made, striking types have been chosen, which are sufficiently characteristic to serve the purposes of general illustration. There are many variations from the conditions which have been described, but these are due to disturbances which have taken place either since the formation of the coal, or during the period of the actual deposition of the coal.

That coal is derived from the vegetable kingdom, no longer admits of a doubt; but the class of plants to which more especially we are to look for the origin of coal, is still a matter of much uncertainty; and the conditions under which the change is brought about are very imperfectly understood, and indeed by many geologists utterly misconceived. The idea generally entertained is, that—already described in part—which supposes a natural basin in which vegetable matter is deposited, the layers, according to circumstances, varying in thickness, which become covered with mud or sand, and were thus entombed; the decomposition and disintegration breaking up the vegetable structure, goes on for ages.
Micrometric observers assure us that they are enabled to detect ligneous structure in the bituminous coal. Mr. Quatrefages gives a great number of drawings in proof of this, and he refers the coal to the woody matter of an extinct class of the Conifera. Botanists of eminence, however, assure us that there is no evidence of ligneous structure in any of the examples brought forward in proof of that hypothesis.

Sir Charles Lyell, in his excellent Manual of Elementary Geology, enters largely and with his usual profound manner into the consideration of the vegetable remains. There can be no doubt of the existence of the remarkable fossils described by him during the period when our beds of fossil coal were forming. Referring to Sir William Logan as his authority, Sir Charles says: "It was observed, that while in the overlying shales or "roof" of the coal, ferns and trunks of trees abound, without any stigmata, and are flattened and compressed, those singular plants of the underclay (the stigmata) very often retain their natural forms of branching freely, sending out their slender leaf-like rootlets, formerly thought to be leaves, through the mud in all directions." This plant is singularly indicative of the class of plants from which coal has been derived.

M. Adolph Bronnroth states that the number of species of carboniferous plants amounts to about 500. Lindley informs us that no less than 250 ferns have been obtained from the coal strata. Forty species of fossil plants of the coal period have been referred to the Lycopodiales. These, with Equisetum, Colacites, Astreptophyllum, Sigillaria, of which about thirty-five species are known with their roots, Stigmaria and Conifera, make up the remarkable flora which have been preserved to us in our coal series.

Trees and humber plants in great variety are found in the carboniferous sandstones and shales, and in the coal itself, but it does not appear that we have any one evidence of the actual conversion of the woody fibre of these plants into coal; that is, there is no evidence of the direct conversion of wood into bituminous coal. The trees are almost invariably silicified, or converted into columns of sandstone; the carbon which constituted the original woody fibre being substituted by silica, or sometimes by carbonate of lime, and sometimes by iron. Sir Charles Lyell has carefully examined the phenomena, now in progress, of the great delta of the Mississippi, and he perceives in them many facts which fully explain, to his mind, the progress of coal. It cannot, however, be disguised, that even while he refers the coal to the supposed submerged forests, he does not venture to explain any of those changes, which he evidently believes depend upon some peculiar conditions of climate.

Professor John Phillips, who has devoted much study to this subject, says: "There is no necessity to enlarge upon the proofs of the origin of coal from vegetables, drawn from an examination of its chemical constitution, as compared with the vegetable products, and the composition of the ligneous parts of the plants, and from the unanswerable identity of the carbonaceous substance, into which a vast multitude of fossil plants have been converted. The chemical constitution of this carbonaceous product of the individual vegetables, is exactly analogous to the chemical constitution of coal; and it is quite probable that hereafter the reason of the variations to which both are subject, whether dependent on the original nature of the plant or produced by unequal exposure to decay after immersion, or metamorphic subsequent operations, will be as apparent as that of the general argument arising from a common vegetable origin."—Manual of Geology.

Mr. Jukes says: "If, therefore, we suppose wood (or vegetable matter) buried under accumulations of more or less porous rock, such as sandstone and shale, so that it might rot and decompose, and some of its elements enter into new combinations, always using up a greater quantity of oxygen and nitrogen than of carbon and hydrogen, or of oxygen and hydrogen than of carbon, we should have the exact conditions for the transformation of vegetable matter into coal."—The Student's Manual of Geology.

Much stress has been laid upon the fact that we have brown coal still retaining all the unmistakable characters of wood, and the apparent passage of this into true coal. Zumpt states that the timber in the coal mines of Charlottenbrunn is sometimes converted into brown coal. The same conversion was many years ago found in an old gallery of an iron mine at Turrach in Styria. A. Schröter explains, according to the analysis made by him, this conversion, by the separation of marsh gas and carbonic acid from the ligneous fibre of oak wood.—Bischof.

The same authority says: "This conversion of wood into coal may take place in four different ways, namely:"

1. By the separation of carbonic acid and carburetted hydrogen.
2. " carbonic acid and water.
3. " carburetted hydrogen and water.
4. " carbonic acid, carburetted hydrogen and water."

Quoting the information accumulated by Bischof for the purpose of showing the chemical changes which take place, the following analyses are given:
Such is, in the main, the evidence brought forward in support of the view that coal is the result of the decomposition, upon the place where it is found, of woody fibre. The following remarks by Professor Henry Rogers on the structure of the Appalachian coal exhibit some of the difficulties which surround this view:

1. Each bed is made up of innumerable very thin laminae of glossy coal, alternating with equally minute plates of impure coal, containing a small admixture of finely divided earthy matter. These subdivisions, differing in their lustre and feature, are frequently of excessive thinness, the less brilliant leaves sometimes not exceeding the thickness of a sheet of paper. In many of the purer coal-beds these thin partings between more lustrous layers consist of little laminae of pure fibrous charcoal, in which we may discover the peculiar texture of the leaves, fronds, and even the bark of the plants which supplied a part of the vegetable matter of the bed. All these ultimate divisions of a mass of coal will be found to extend over a surprisingly large surface, when we consider their minute thickness. Pursuing any given brilliant layer, whose thickness may not exceed the fourth part of an inch, we may observe it to extend over a superficial space which is wholly incompatible with the idea that it can have been derived from the flattened trunk or limb of any arborescent plant, however compressible. When a large block of coal is thus minutely and carefully dissected, it very seldom, if ever, gives the slightest evidence of having been produced from the more solid parts of trees, though it may abound in fragments of their fronds and deciduous extremities.

It is not possible, within the space which can be afforded to this article in the present work, to examine further the various views which have been entertained by geologists and chemists of the formation of coal. A brief summary must now suffice.

1. Coal is admitted upon all hands to be of vegetable origin.

2. Many refer coal to some peculiar changes which have taken place in wood; others to the formation and gradual subsidence of peat bogs, (Unger.) Fuel have also been thought by others to supply the materials for coal-beds.

3. By some the coal is thought to be formed upon the spots on which the trees grew and decayed. By others it is supposed that vast masses of vegetable matter were drifted into lakes or deltas, to be there decomposed.

4. Whether the plants grew on the soil—the under clay—upon which the coal is found, or were drifted to it, there must have been long periods during which nothing but vegetable matter was deposited, and then a submergence of this land, and vast accumulations of mud and sand. The number of coal seams in some of our coal-fields, and the thicknesses of the strata above them, have been already given.

Henry Rogers and others suppose, that the whole period of the coal measures was characterized by a general slow subsidence of the coasts on which we conceive that the vegetation of the coal grew; that this vertical depression was, however, interrupted by penes and gradual upward movements of less frequency and duration, and that these nearly statical conditions of the land, alternated with great paroxysmal displacements of the level, caused by the mighty pulsations of earthquakes. (See Faults.)

The difficulties are mainly the facts—

1. That the evidence is not clear that any thing like ligneous structure can be detected in coal.

2. That the woody matter found in coal is never converted into coal, although sometimes it appears as if the bark was so changed.

3. That the coal arranges itself always in exact obedience to the underlying surface, as though a semi-fluid mass had been spread out on a previously formed solid bed.

4. The thinning out of true coal to extreme thinness, as mentioned by Professor Rogers, numerous examples of which appear in this country.

5. The extreme difficulty connected with the subsidence of the surface of the earth to such a depth as to which the lowest seams of coal extend.
We do not intend to answer any of those difficulties, but to leave the question open for further examination, merely remarking, in conclusion, that there can be no doubt of the vegetable origin of coal; the only question is, the conditions of change by which bituminous coal has been produced from vegetable fibre; and, that we have not completed all the links in the chain between brown coal and true coal.

In concluding this notice of mineral fuel, it may be worth while to draw attention to the vast and overwhelming importance of the subject, by a reference both to the absolute and relative value of the material, especially in the British Islands. It may be stated as probably within the true limit, if we take the annual produce of the British coal mines at 65,000,000 tons, the value of which is not less than £18,700,000 sterling at the pits' mouth, which may be estimated at the place of consumption, and therefore including a certain amount of transport cost necessary to render available the raw material, at not less than £20,000,000. The capital employed in the coal trade is now estimated at £18,500,000.

We have, therefore, the following summary, which will not be without interest:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of the coal annually raised in Great Britain, estimated at the pit mouth</td>
<td>£16,700,000</td>
</tr>
<tr>
<td>Mean annual value at the place of consumption</td>
<td>20,000,000</td>
</tr>
<tr>
<td>Capital engaged in the coal trade</td>
<td>18,500,000</td>
</tr>
<tr>
<td>Mean annual value, at the furnace, of iron produced from British coal</td>
<td>14,545,000</td>
</tr>
</tbody>
</table>

COAL BRASSES. *Iron pyrites, sulphide of iron,* found in the coal measures. These are employed in Yorkshire and on the Tynes in the manufacture of copperas, the protosulphate of iron. For this purpose they are exposed in wide-spread heaps to atmospheric action; the result is the conversion of the sulphur into sulphuric acid, which, combining with the iron, forms the sulphate of the protoxide of iron, which is dissolved out and recrystallized.

The iron ores called Brass, occurring in the coal measures of South Wales, were particularly described by E. Chambers Nicholson and David S. Price, Ph.D., F.C.S., at the meeting of the British Association at Glasgow. Their remarks and analyses were as follows:

"There are three kinds of ores to which the name brass is applied; they are considered to be an inferior class of ore, and are even rejected by some iron-masters. One is compact, heavy, and black, from the admixture of coaly matter, and exhibits, when broken, a coarsely pisiform fracture. A second is compact and crystalline, not unlike the darkest-colored mountain limestone of South Wales in appearance. The third is similar in structure to the first-named variety; the granules, consisting of iron pyrites, are mixed with coaly matter, and cemented together by a mineral substance, similar in composition to the foregoing ores. It is from the yellow color of this variety that the name brass has been assigned to the ores by the miners. The ores have respectively the following composition:

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate of iron</td>
<td>68.71</td>
<td>59.73</td>
<td>17.74</td>
</tr>
<tr>
<td>Carbonate of manganese</td>
<td>0.42</td>
<td>0.37</td>
<td>-</td>
</tr>
<tr>
<td>Carbonate of lime</td>
<td>9.86</td>
<td>11.80</td>
<td>14.19</td>
</tr>
<tr>
<td>Carbonate of magnesia</td>
<td>11.80</td>
<td>15.55</td>
<td>12.06</td>
</tr>
<tr>
<td>Iron pyrites</td>
<td>0.32</td>
<td>trace</td>
<td>49.72</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>0.17</td>
<td>0.29</td>
<td>trace</td>
</tr>
<tr>
<td>Coaly matter</td>
<td>8.87</td>
<td>8.80</td>
<td>6.10</td>
</tr>
<tr>
<td>Clay</td>
<td>-</td>
<td>270</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>99.55</td>
<td>100.18</td>
<td>99.81</td>
</tr>
</tbody>
</table>

"It is unnecessary to allude to the third variety; as an iron-making material, its color admits of its being at all times separated from the others. The pyrites which it contains, we may remark, is blainsphered of iron.

"It is to the ores I. and II. that we would direct attention. The reason of their having hitherto been comparatively disregarded may be attributed either to their having been mistaken for the so-called brass of coal, or to their being difficult to work in the blast-furnace in the ordinary manner, through the belief that they were similar in construction to the argillaceous ores of the district. It will be seen from the above analyses that they are varieties of spathic iron ore, in which the magnesia has been replaced by other bases. If treated judiciously, they would smelt with facility, and afford an iron equal to that produced from the argillaceous ores. From the large amount of lime and magnesia which they contain, their employment must be advantageous in an economic point of view.
COAL-GAS.

"An interesting feature in these ores is their fusibility during calcination on the large scale. When this process is conducted in heaps, the centre portions are invariably melted. This, considering the almost entire absence of silica, is apparently an unexpected result. The fixed mass is entirely magnetic and crystalline. Treated with acids, it dissolves with great evolution of heat.

"The following is its composition:

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage of Carbon</th>
<th>Percentage of Hydrogen</th>
<th>Percentage of Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protoside of iron</td>
<td>35.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sesquioxide of iron</td>
<td>32.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protoside of manganese</td>
<td>0.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime</td>
<td>12.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesia</td>
<td>13.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siliee acid</td>
<td>1.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alumina</td>
<td>0.51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

"From the above analysis, it is probable that the fusibility of the compound is owing to the magnetic oxide of iron acting the part of an acid. When thoroughly calcined and unfused, the ores retain their original form; and if exposed to the air for any length of time, crumble to powder from the absorption of water by the alkaline earths."

COAL-GAS. Before proceeding to describe the actual processes now employed for the generation of illuminating gas, it will be advisable to consider briefly the general scientific principles involved in those processes, and especially the chemical relations of the materials employed for the generation and purification of illuminating gas, together with the bearings of chemistry upon the operations of generating, purifying, and burning such gas.

The Chemistry of Gas-Manufacture.—The chief materials employed in the manufacture of gas for illuminating purposes are, coal, oil, resin, peat, and wood. These materials, although very dissimilar in appearance, do not essentially differ from each other in their chemical constituents, they may all be regarded as consisting chiefly of the elements, carbon, hydrogen, and oxygen, and their value for the production of illuminating gas increases with the increase of the proportion of hydrogen, and with the diminution of the relative amount of oxygen. Accordingly we find that oil and resin generally produce gas larger in volume and better in quality than coal, whilst peat and wood, owing to the large proportion of oxygen which they contain, are greatly inferior to coal for the purposes of the gas manufacturer. The relative proportions of carbon, hydrogen, and oxygen, in the organic part of these substances, is seen from the following comparison:

In addition to the three essential constituents above mentioned, most of these materials contain small and variable proportions of sulphur, nitrogen, and inorganic matter, the latter constituting, when the substance is burnt, what we term ash. When these substances are heated to redness, they undergo decomposition, a considerable quantity of inflammable gases and vapors being evolved, whilst a residue, consisting of carbon, or of carbon and ash, remains behind in the solid form. When atmospheric air has free access during this heating operation, the inflammable gases and vapors burn with a more or less bright flame, as in a common fire; whilst the carbonaceous residue continues afterwards to glow, until nearly the whole of the carbon is consumed. If, however, the application of heat be made without access of air, by inclosing the materials, for instance, in an iron retort provided only with an outlet for the escape of gases, the decomposition goes on in much the same manner as before, but the various products formed, being no longer exposed to the simultaneous action of atmospheric oxygen, do not undergo combustion; the inflammable gases and vapors are evolved through the outlet pipe in an unburnt condition, and the carbonaceous residue also remains unconsumed in the retort. Upon cooling the gases and vapors thus evolved, the latter condense more or less into liquids which separate into two layers, the lower one forming a dense black oily fluid, commonly known as tar, and containing several solid
COAL-GAS.

hydrocarbons partly in solution and partly in suspension; whilst the other one consists chiefly of an aqueous solution of salts of ammonia, if the organic matters operated upon contained nitrogen. Thus the volatile products of this process of destructive distillation consist of solids, liquids, and gases. These constituents may be thus tabulated:—

I. GASEOUS.

<table>
<thead>
<tr>
<th>Name</th>
<th>Chemical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H</td>
</tr>
<tr>
<td>Light carburetted hydrogen</td>
<td>C₂H₄</td>
</tr>
<tr>
<td>Carbonic oxide</td>
<td>CO</td>
</tr>
<tr>
<td>Olefiant gas</td>
<td>C₂H₄</td>
</tr>
<tr>
<td>Propylene</td>
<td>C₃H₆</td>
</tr>
<tr>
<td>Butylene</td>
<td>C₅H₁₀</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>CO₂</td>
</tr>
<tr>
<td>Sulphuretted hydrogen</td>
<td>SH</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
</tr>
</tbody>
</table>

II. LIQUID.

<table>
<thead>
<tr>
<th>Name</th>
<th>Chemical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqueous layer:</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>HO</td>
</tr>
<tr>
<td>Oily layer:</td>
<td></td>
</tr>
<tr>
<td>Bisulphide of carbon</td>
<td>CS₂</td>
</tr>
<tr>
<td>Benzol</td>
<td>C₆H₆</td>
</tr>
<tr>
<td>Tolol</td>
<td>C₆H₁₂</td>
</tr>
<tr>
<td>Cumol</td>
<td>C₆H₁₂</td>
</tr>
<tr>
<td>Cymol</td>
<td>C₆H₁₂</td>
</tr>
<tr>
<td>Aniline</td>
<td>C₆H₁₂</td>
</tr>
<tr>
<td>Picoline</td>
<td>C₆H₁₂</td>
</tr>
<tr>
<td>Lecolene</td>
<td>C₆H₁₂</td>
</tr>
<tr>
<td>Carabolic acid</td>
<td>C₆H₁₂</td>
</tr>
<tr>
<td>Other hydrocarbons</td>
<td>C₆H₁₂ + 2</td>
</tr>
<tr>
<td></td>
<td>C₆H₁₂ — 6</td>
</tr>
</tbody>
</table>

III. SOLID.

<table>
<thead>
<tr>
<th>Name</th>
<th>Chemical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>In aqueous layer:</td>
<td></td>
</tr>
<tr>
<td>Carbonate of ammonia</td>
<td>NH₄CO³</td>
</tr>
<tr>
<td></td>
<td>NH₄CO₃+ HS</td>
</tr>
<tr>
<td>Sulphate of ammonia</td>
<td>NH₄SO₄</td>
</tr>
<tr>
<td></td>
<td>NH₄Cl</td>
</tr>
<tr>
<td>In oily layer:</td>
<td></td>
</tr>
<tr>
<td>Paraffine</td>
<td>C₆H₁₄</td>
</tr>
<tr>
<td>Naphthaline</td>
<td>C₁₀H₁₂</td>
</tr>
<tr>
<td>Phenanthraline</td>
<td>C₁₄H₁₂</td>
</tr>
<tr>
<td>Pyrene</td>
<td>C₁₄H₁₄</td>
</tr>
<tr>
<td>Chrysene</td>
<td>C₁₆H₁₃</td>
</tr>
</tbody>
</table>

In practice, there is not such a perfect separation of the products as is represented in the above table; thus a small proportion of the gases dissolves in the liquid products, whilst most of the liquids, and even some of the solids, diffuse themselves in the form of vapor, to a certain extent, into the gases; and the solids are in most cases almost completely dissolved in the liquids. The relative proportions also in which these products occur greatly depend upon the temperature employed in the destructive distillation, and the length of time during which the volatile products are exposed to it; a low temperature and short exposure favoring the formation of solids and liquids, whilst a higher heat and longer exposure determine the production of a larger proportion of gases at the expense of the solids and liquids.

The usual process of gas-making consists in exposing coal or cannel to a bright-red heat, in close vessels of convenient size and shape, until all, or the greater part, of the volatile matter is expelled. Coke is the material left in the retort, and the matters volatilized consist of condensible vapors, and of permanent gases more or less saturated with these vapors. By a simple process of refrigeration nearly the whole of the vapors may be readily condensed, thus separating the gases more or less perfectly from the liquid and solid products of the distillation. But this preliminary process of purification leaves the gases still in a state totally unfit for use in the production of artificial light. They still retain constituents, which are either noxious in themselves, or generate noxious compounds when they are burnt, such as sulphuretted hydrogen, sulphide of ammonium, carbonate of ammonia, and bisulphide of carbon. They also contain carbonic acid, which greatly diminishes the amount of light yielded by the illuminating gases with which it is mixed.

* Here n means an even number, as 2, 4, 6, &c.
Besides these injurious ingredients, which may be conveniently included in the term *impurities*, there are others which do not contribute anything to the illuminating power of the mixture, and which may be denominated *diluents*. We can thus classify the constituents of coal-gas as follows:

<table>
<thead>
<tr>
<th>Illuminating Ingredients</th>
<th>Diluents</th>
<th>Impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbon vapors of the formula CnHn and CnH(n - 6).</td>
<td></td>
<td>Carbonic acid.</td>
</tr>
<tr>
<td>Vapors of hydrocarbons of the formula CnH(n - 12.)</td>
<td></td>
<td>Vapor of bisulphide of carbon.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nitrogen.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxygen.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aqueous vapor.</td>
</tr>
</tbody>
</table>

As the intelligent manufacture of gas for illuminating purposes requires a knowledge of the leading properties of the compounds included under the three heads just mentioned, we will now proceed briefly to describe them.

**I. ILLUMINATING INGREDIENTS.**

**Olefiant Gas.**—This gas has been proved by Berthollet to exist in coal-gas, and it is probably always a constituent of the illuminating gases from resin, oil, peat, and wood. It is occasionally, though rarely, met with in nature, as a product of the action of volcanic heat upon coal-bearing strata; it never occurs, however, in coal strata under ordinary circumstances, and no trace of it has ever been met with amongst the gases issuing from the coal strata of this country, and which have been investigated by Graham, Playfair, and others. Olefiant gas can be prepared nearly pure by heating in a glass retort a mixture of 1 part by weight of alcohol, and 6 parts of oil of vitriol. The gas must be passed through solution of caustic soda, to remove sulphurous and carboionic acids with which it is generally contaminated.

Olefiant gas is colorless, and possesses a peculiar and slightly unpleasant odor. Its specific gravity is, rather less than that of atmospheric air, being 0.934; 100 cubic inches, at 60° F., and 30 inches barometrical pressure, weigh 30-3418 grains. It consists of two volumes of carbon vapor and four volumes of hydrogen, the six volumes being condensed to two. It contains, in a given bulk, exactly twice as much carbon as is contained in light carburetted hydrogen. Olefiant gas is inflammable, but does not support combustion: when inflamed as it issues from a jet into the atmosphere, it burns with a white flame, emitting a very brilliant light without smoke. In burning, it consumes three times its volume of oxygen, and produces twice its volume of carboionic acid. Exposed to a full red heat, as in passing through a red-hot tube, it is rapidly decomposed, carbon being deposited, whilst hydrogen and light carburetted hydrogen are produced; exposure to a full red heat consequently soon entirely destroys its illuminating power.

**Propylene and Butylene.—**The first of these highly illuminating constituents of coal-gas may be obtained by passing the vapor of fixed oil through a red-hot tube, and the second by the electric decomposition of valerate of potash. Both these gases are colorless, possess a slight ethereal odor, and burn with a brilliant white flame. Like olefiant gas, they are rapidly decomposed at a bright-red heat, depositing much carbon, and being converted into the non-illuminating gases—hydrogen and light carburetted hydrogen. Propylene consists of three volumes of carbon vapor and six volumes of hydrogen condensed to two volumes. It therefore contains, in a given volume, one-half more carbon than olefiant gas. Its specific gravity is 1-4511.

Butylene consists of four volumes of carbon vapor and eight volumes of hydrogen, the twelve volumes being condensed to two; it consequently contains, in a given volume, twice as much carbon as olefiant gas. Its specific gravity is 1-9348.

**Vapors of Hydrocarbons of the Form CnHn.**—A considerable number of compounds having this formula are known to exist in coal-tar, and, as many of them are very volatile, they must be diffused as vapors in coal-gas; but as they have not yet been successfully disentangled from each other, no account of their individual properties can be given; they all, however, contain more carbon in a given volume than butylene, and must therefore contribute, proportionally to their volume, a greater illuminating power than any of the gaseous hydrocarbons. They are all readily decomposed at a bright-red heat, chiefly into carbon and non-illuminating gases.

**Vapors of Hydrocarbons of the Formula CnH(n - 6).**—Those consist chiefly of benzol, toluol, cumol, and cymol, compounds which, being components of the more volatile portion
of the tar, diffuse themselves into the gaseous products of distillation, contributing in no inconsiderable degree to the total illuminating effect of the gas. The composition of these substances has been already given in the Table; and it is therefore only necessary here to remark, that benzol vapor contains, in a given volume, three times as much carbon as olefiant gas, whilst the vapors of toluol, cumol, and cymol, contain respectively 34, 49, and 5 times the amount of carbon contained in olefiant gas. For a further account of these and the following hydrocarbons, see Coal Naphtha, Destructive Distillation.

Vapors of Hydrocarbons of the Formula CnH₂₄n—12.—The only vapor of this composition known to be present in coal-gas is naphthaline, (C₁₇H₁₄) which, although a solid at ordinary temperatures, yet emits a considerable quantity of vapor; in fact, its presence occasions to a great extent the peculiar odor of coal-gas.

Naphthaline is a frequent source of serious annoyance to the gas manufacturer, by condensing in the street mains and gradually blocking them up, or so narrowing their bore as to prevent the passage of the needful supply of gas. This effect can only be produced, when the gas charged with naphthaline vapor is allowed to leave the holder at a temperature higher than that of the mains through which it subsequently flows; but as this cannot always be avoided, the prevention of such deposits might perhaps be best effected by passing the gas over a large surface of coal oil before it is led into the mains. The oil would absorb so much of the naphthaline as to prevent any subsequent deposition. The vapor of naphthaline contains, in an equal volume, five times as much carbon as olefiant gas. The amount of light yielded by these illuminating constituents is directly proportionate to the amount of carbon contained in an equal volume of each; taking, therefore, the illuminating power of olefiant gas as unity, the following numbers exhibit the relative illuminating values of equal volumes of the several luminous constituents of gas:

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>Relative Illumination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propylene</td>
<td>- 1.5</td>
</tr>
<tr>
<td>Butylene</td>
<td>- 2.0</td>
</tr>
<tr>
<td>Amylene</td>
<td>- 2.5</td>
</tr>
<tr>
<td>Hydride of amyl</td>
<td>- 2.5</td>
</tr>
<tr>
<td>Hydride of hexyl</td>
<td>- 3.0</td>
</tr>
<tr>
<td>Hexyne</td>
<td>- 3.0</td>
</tr>
<tr>
<td>Naphthaline</td>
<td>- 5.0</td>
</tr>
</tbody>
</table>

II. Diluents.

Hydrogen.—This element constitutes one-ninth of the total weight of the waters of our globe, and with one or two unimportant exceptions, enters into the composition of all animal and vegetable substances and of the products derived from them, as peat, coal, oils, bitumen, &c. It is, however, very rarely met with in nature in a free or uncombined state; having hitherto only been thus found in the gases emitted from volcanoes.

Hydrogen gas may be obtained in abundance and nearly pure by passing steam over iron, zinc, and several other metals, in a fine state of division, at a full red heat. Mixed with carbonic oxide and carbonic acid gases, it is also generated in large quantity when steam is passed over charcoal, coke, or other carbonaceous substances at a red heat. In all these cases the water vapor is decomposed, its hydrogen being liberated, whilst its oxygen unites with the metal or carbon, forming in the first case a solid non-volatile oxide, which encrusts the pure metal, and soon stops further action; in the second case a gaseous oxide of carbon is generated, and passes off along with the hydrogen, thus leaving the carbon freely exposed to the further action of the watery vapor. When carbon is used, that portion of the steam which is converted into hydrogen and carbonic oxide yields its own volume of each of these gases; and that portion which forms hydrogen and carbonic acid affords its own volume of hydrogen and half its own volume of carbonic acid. The amount of watery vapor which undergoes the latter decomposition decreases as the temperature at which the operation is conducted increases. At a white heat scarcely a trace of carbonic acid is produced.

Hydrogen is the lightest of all known bodies, its specific gravity being only -0091; 100 cubic inches, at 60° Fahr., and 30 inches barometric pressure, weigh only 2'1371 grains. It has a powerful affinity for oxygen, but develops scarcely any light during combustion; when, however, solid substances, such as lime, magnesia, or platinum, are held in the flame of hydrogen, considerable light is emitted. Burnt in air or oxygen gas, it is entirely converted into watery vapor, which condenses upon cold surfaces held above the flame.

Light Carbonic Hydrogen.—This gas consists of carbon and hydrogen in the proportion of 6 parts by weight of the former element combined with 2 parts of the latter. Owing to its being copiously generated in marshy swampy places, it is frequently termed marsh gas, and from certain considerations relative to its chemical constitution, it has more recently received the name of hydride of methyl. It enters largely into the composition of coal-gas, and is also a natural product of the slow decomposition of putrefaction in general. Thus it occurs in enormous quantities in the coal strata, and bubbles up from stagnant pools and ditches which contain putrefying organic remains. As thus
generated, it is mixed with small quantities of carbonic acid and nitrogen; it can, however, be artificially prepared perfectly pure, but the processes need not be described here.

Light carburetted hydrogen when pure is colorless, tasteless, and inodorous; it is neutral to test papers, and nearly insoluble in water; its specific gravity is 0.045, and 100 cubic inches, at 60° Fahr., and 60 inches barometric pressure, weigh 17.446 grains. It does not support combustion or respiration, but is inflammable, burning with a blue, or slightly yellow flame, yielding scarcely any light. Mixed with a due proportion of atmospheric air or oxygen, and ignited, it explodes with great violence: the products of its combustion are water and carbonic acid.

When light carburetted hydrogen is exposed to a white heat, it is slowly decomposed, depositing carbon, and yielding twice its volume of hydrogen.

Carbonic Oxide.—This gas consists of 6 parts by weight of carbon, and 8 parts of oxygen. It is formed when carbon is consumed in a limited quantity of air or oxygen, and is also generated, as stated above, when steam is passed over ignited coke or charcoal, or when coal tar and steam meet in a red-hot vessel. It is always a constituent of coal-gas.

Carbonic oxide is a colorless and inodorous gas, rather lighter than atmospheric air, and having exactly the specific gravity of oleanant gas, 0.977; it is very sparingly soluble in water, but readily soluble in ammoniacal solution of chloride of copper. Carbonic oxide is inflammable, burning with a beautiful blue flame almost devoid of light; the product of its combustion is carbonic acid. It is said to be very poisonous.

III. IMPURITIES.

Sulphured Hydrogen.—This gas consists of sixteen parts of sulphur and one part of hydrogen; it may be produced by passing hydrogen along with the vapor of sulphur through a red-hot tube, but it is best prepared pure by decomposing proto-sulphuret of iron with dilute sulphuric acid, and collecting the evolved gas at the pneumatic trough or over mercury. It is always an ingredient in crude coal, peat, or wood-gas.

Sulphured hydrogen is a colorless gas, of a very noxious odor, resembling that of putrid eggs; its specific gravity is 1.1746. It is highly inflammable, burning with a blue flame, destitute of light, and generating a large amount of sulphurous acid: it is chiefly this latter circumstance which renders its presence in coal-gas objectionable. It is readily absorbed by metallic solutions, by hydrated oxide of iron, and by lime both in the wet and dry state, and is easily recognized in coal-gas by exposing a strip of paper impregnated with acetate of lead to a stream of the gas; if the paper becomes discolored, sulphured hydrogen is present.

Hydrogen Sulphate of Sulphide of Ammonium.—This compound is formed by the combination of equal volumes of ammonia and sulphured hydrogen. It consists of 14 parts by weight of nitrogen, 15 of hydrogen, and 82 of sulphur. It is always largely produced in the manufacture of coal-gas, but is almost completely condensed and retained in the aqueous layer of liquid products, contributing principally to the unbearable odor of gas lignum: a mere trace of this body is therefore present in crude coal-gas. When quite pure it is a colorless crystalline solid, very soluble in water, and volatile at ordinary temperatures. Its vapor, when present in coal-gas, is absorbed and decomposed by hydrate of lime both in the wet and dry state, ammonia being liberated. It is also decomposed by acids, but in this case the ammonia is retained by the acid, whilst sulphured hydrogen is evolved.

Carbonic Acid.—This gas is met with in nature as a constituent of atmospheric air, and is produced in large quantities during the earlier stages of the formation of coal in the earth's strata. Thus, in the lignite districts of Germany, it is copiously evolved, and meeting with water in its passage to the surface, it is absorbed, and forms those sparkling mineral springs commonly known as seltzer-water.

Carbonic acid is also formed during fermentation, by the combustion of carbon in air, and in the decomposition of water by carbon at a red heat.

At ordinary temperatures carbonic acid is a colorless and invisible gas, but it may be liquefied by very intense cold or pressure. It consists of 6 parts, by weight, of carbon united with 16 parts of oxygen, and thus differs from carbonic oxide by containing twice as much oxygen as the latter gas. By passing carbonic acid over ignited coke, charcoal, or other carbonaceous matters, it takes up as much carbon as it already contains, and becomes converted into carbonic oxide; but it is impossible in this way to convert the whole of the carbonic acid into carbonic oxide unless the process be very frequently repeated. Carbonic acid is pungent, acridulent, and soluble in an equal bulk of water, to which it communicates that briskness which we so much admire in soda-water; it is considerably heavier than atmospheric air, its specific gravity being 1.524. This gas is unflammable, and cannot support combustion or animal life. Its acid properties are not strongly developed, but it unites readily with alkaline bases, forming carbonates: it is upon this property that the removal of carbonic acid from coal-gas depends. On passing coal-gas containing this acid through slaked lime in fine powder, or through milk of lime, the whole of the carbonic acid disappears, having united with the lime. Quick-lime, slaked in such a manner as to be neither dust-dry nor very perceptibly moist, is most effective for the absorption of high per-
centages of carbonic acid, a layer three inches in thickness not allowing a trace of the acid gas to pass through it.

The presence even of a small percentage of carbonic acid in coal-gas is much to be deprecated, on account of the great loss of light which it occasions, 1 per cent. of carbonic acid diminishing the illuminating power of coal-gas to the extent of about 6 per cent.; the addition which it makes to the carbonic acid produced during combustion is, however, too minute to be of any importance.

**Carbonate of Ammonia.**—During the destructive distillation of coal, a considerable proportion of the nitrogen contained in the coal is converted into carbonate of ammonia, the greater part of which condenses in the aqueous layer of liquid products; but as carbonate of ammonia is very volatile, even at ordinary temperatures, crude coal-gas always contains a small quantity of this compound. It is a volatile, white, crystalline solid, very soluble in water, and possessing a pungent smell like ammonia. Its vapor is decomposed by lime, which unites with carbonic acid, liberating ammonia. The presence of this salt, or of ammonia, in coal-gas, is very undesirable, as it corrodes brass fittings, and is also partially converted into nitrous acid during the combustion of the gas.

**Bisulphide of Carbon.**—This compound consists of 6 parts, by weight, of carbon, and 32 parts of sulphur; it is formed whenever sulphur and carbonaceous matter are brought together at a bright-red heat, and therefore, owing to the presence of sulphur in all varieties of coal, its vapor is generally, and probably always, present in coal-gas. Bisulphide of carbon is a colorless liquid, of a most insupportable odor, resembling garlic; it is very volatile, boiling at 108°. It does not mix with water, but dissolves in alcohol and ether; it is also very soluble in solutions of caustic soda or potash in methylic, ethylic, or amylic alcohol. It is very inflammable, and generates during combustion much sulphurous acid; on this account its presence in coal-gas is very injurious, and as there is no known means of removing it on a large scale by any mode of purification, its non-generation in the process of gas-making becomes a problem of great importance. Few attempts have yet been made to solve this difficulty, but Mr. Wright, the eminent engineer of the Western Gas Company, has observed that its formation is greatly hindered, if not entirely prevented, by the employment of a somewhat moderate temperature. In corraboration of this observation it has frequently been noticed that the gas furnished by companies who use a high heat contains a very large quantity of this noxious material, whilst gas generated at lower temperatures, as, for instance, that produced by White's hydrocarbon process, contains mere traces of this compound. Although no process for the absorption of bisulphide of carbon vapor from coal-gas is sufficiently cheap for employment on a large scale, yet advantage might be taken of its solubility in a solution of caustic potash in fusel oil (a by-product in spirit distilleries) or in methylated spirit of wine, for its removal from the gas supplied to private houses, where the damage done by the sulphurous acid is most annoying. By passing the gas over a considerable surface of this solution, contained in a small private purifier, the bisulphide of carbon vapor is completely removed.

Bisulphide of carbon vapor can be readily detected in coal-gas by a very simple apparatus devised by Mr. Wright:* in this instrument the products of the combustion of a jet of gas are made to pass through a small Liebig's condenser; if the liquid dropping from this condenser strongly reddens blue litmus-paper, it is highly probable that bisulphide of carbon is present. As a decisive test, 50 or 60 drops of the condensed fluid should be collected in a small test-tube, and a few drops of pure nitric acid added: on heating this mixture to boiling over a spirit-lamp, and then adding a drop or two of a solution of chloride of barium, the liquid will become more or less milky if bisulphide of carbon has been present in the gas. It is necessary here to remark, that the absence of sulphuretted hydrogen must be first ascertained by the non-coloration of paper immersed with acetate of lead, and held for some minutes in a stream of the gas.

**Nitrogen.**—This gas is the chief constituent of atmospheric air, 100 cubic feet of air containing rather more than 79 cubic feet of this gas. It also enters into the composition of a large number of animal and vegetable substances. All descriptions of coal contain small quantities of this element. When nitrogen is eliminated from combination in contact with oxygen, it usually takes the form of nitrous or nitric acid; whilst in contact with an excess of hydrogen it generates ammonia. It is in this latter form that it is eliminated from coal in the process of gas-generation.

Nitrogen is a colorless, inodorous, and tasteless gas, of specific gravity 0.976. It is incombustible under ordinary circumstances, and instantaneously extinguishes burning bodies. Under certain conditions, however, nitrogen does undergo combustion, as when it is exposed to a very intense heat in the presence of oxygen. This occurs, for instance, when a small quantity of nitrogen is added to a mixture of hydrogen, with a somewhat larger proportion of oxygen than is requisite to form water, and the mixture then ignited: a loud explosion takes place, and a considerable quantity of nitric acid is formed, owing to combustion of the

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* This instrument can be had on application to Mr. Wright, 55 and 55a, Millbank Street, Westminster, S. W.
COAL-GAS.

nitrogen, or, in other words, its union with oxygen gas. This formation of nitric acid possibly occurs also to a limited extent during the burning of coal-gas; and as the temperature required to form nitric acid is very high, the greater the volume of gas consumed from one burner in a given time, the greater will be the relative quantity of nitric acid produced. The formation of such a corrosive material as nitric acid under these circumstances shows the importance of preventing the admixture of the products of the combustion of coal-gas with the atmosphere of the apartments in which it is consumed. The nitrogen contained in coal-gas is due entirely to the admission of atmospheric air, and not to the elimination of the nitrogen contained in the coal; for this latter nitrogen appears to be evolved only in combination with hydrogen as ammonia. As nitrogen is incombustible, it is not only a useless ingredient in coal-gas, but, owing to its abstracting heat from the flame of such gas, it causes a diminution of light, and is thus decidedly injurious. The admixture of this element ought therefore to be avoided as much as possible.

_Oxygen._—This element is always present in coal-gas, although in very small quantity if the manufacture be properly conducted. It is never evolved from the coal itself, but it makes its way into the gas through leaky joints, and also to a certain extent through the water in which the holders are immersed. Its presence is highly injurious to the illuminating power of the gas; and since, when once introduced, it cannot be abstracted by any practicable means, its admixture ought to be carefully guarded against.

Oxygen is a colorless, invisible, and inodorous gas, very sparingly soluble in water, and which has hitherto resisted all attempts to liquify it by cold or pressure. It is evolved from the leaves of plants under the influence of light, and constitutes about one-fifth of the bulk of our atmosphere. By far the largest amount of oxygen however exists in combination with other elements; thus eight out of every nine tons of water are pure oxygen, and it forms at least one-third of the total weight of the mineral crust of our globe. It is therefore the most abundant of all elements. Oxygen gas is heavier than atmospheric air; 100 cubic inches, at 60° Fahrenheit, and 30 inches barometric pressure, weighing 34-103 grains, whilst 100 cubic inches of the latter weigh only 81-917 grains. The specific gravity of oxygen is 1-1026. It eminently supports combustion, all combustible bodies when introduced into it burning much more vividly than in common air; indeed it is owing to the presence of this gas in our atmosphere, that common air possesses the property of supporting combustion.

_Aqueous vapor._—Water is volatile at all natural temperatures, and therefore its vapor always exists to a greater or less extent diffused in coal-gas, even as delivered to the consumer. The percentage amount of aqueous vapor thus present in coal-gas is always small, even when the gas is saturated; nevertheless the presence of even this small proportion of aqueous vapor diminishes to a certain extent the light produced by the combustion of gas. This effect is no doubt owing to the action of aqueous vapor upon carbon at a high temperature, by which action hydrogen, carbonic oxide, and carbonic acid gases are produced. The presence of aqueous vapor therefore tends to reduce the number of particles of carbon floating in the gas flame, and consequently the light is diminished. The following table shows the maximum percentages of aqueous vapor which can be present in gas at different temperatures. As a general rule the gas will contain the maximum amount at the lowest temperature to which it has been exposed in its passage from the retorts to the burners.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Percentage of aqueous vapor</th>
<th>Temperature</th>
<th>Percentage of aqueous vapor</th>
<th>Temperature</th>
<th>Percentage of aqueous vapor</th>
</tr>
</thead>
<tbody>
<tr>
<td>32° F.</td>
<td>0-6</td>
<td>42° F.</td>
<td>0-9</td>
<td>52° F.</td>
<td>1-3</td>
</tr>
<tr>
<td>33°</td>
<td>0-6</td>
<td>43°</td>
<td>0-9</td>
<td>53°</td>
<td>1-3</td>
</tr>
<tr>
<td>34°</td>
<td>0-7</td>
<td>44°</td>
<td>1-0</td>
<td>54°</td>
<td>1-4</td>
</tr>
<tr>
<td>35°</td>
<td>0-7</td>
<td>45°</td>
<td>1-0</td>
<td>55°</td>
<td>1-4</td>
</tr>
<tr>
<td>36°</td>
<td>0-7</td>
<td>46°</td>
<td>1-0</td>
<td>56°</td>
<td>1-5</td>
</tr>
<tr>
<td>37°</td>
<td>0-7</td>
<td>47°</td>
<td>1-1</td>
<td>57°</td>
<td>1-5</td>
</tr>
<tr>
<td>38°</td>
<td>0-8</td>
<td>48°</td>
<td>1-1</td>
<td>58°</td>
<td>1-6</td>
</tr>
<tr>
<td>39°</td>
<td>0-8</td>
<td>49°</td>
<td>1-1</td>
<td>59°</td>
<td>1-7</td>
</tr>
<tr>
<td>40°</td>
<td>0-8</td>
<td>50°</td>
<td>1-2</td>
<td>60°</td>
<td>1-8</td>
</tr>
<tr>
<td>41°</td>
<td>0-9</td>
<td>51°</td>
<td>1-2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Aqueous vapor has a specific gravity of 0.6201, and one cubic foot of it contains one cubic foot of hydrogen and half a cubic foot of oxygen. In contact with ignited carbon, or carbonaceous substances, it is decomposed; producing a mixture of hydrogen, carbonic oxide, and carbonic acid gases. When passed over ignited iron it yields its own volume of nearly pure hydrogen.

Having thus described the more important properties of the constituents of coal-gas,
we are now prepared to discuss the conditions involved in the generation, purification, and combustion of gas.

On the generation of illuminating gas.—The production of gas for illuminating purposes, whether derived from coal, peat, wood, or oil, depends, as we have seen, upon a rearrangement of the elements composing the material employed. The nature of this rearrangement is dependent upon the temperature employed. The lower the heat at which it can be effected, the lighter the weight of coke or carbonaceous residue left in the retort, and, consequently, the greater the amount of carbon remaining combined with the hydrogen; the hydro-carbons thus formed being chiefly solids and liquids. On the other hand, the higher the temperature employed, the greater is the weight of carbonaceous residue, and, therefore, the smaller is the amount of carbon contained in the volatilized matters, whilst the proportion of gases in these latter becomes larger as the temperature increases. By employing a very low temperature for the destructive distillation, the production of gas may be almost entirely prevented, whilst by the employment of a very high temperature the three chief constituents of coal might without doubt be completely converted into coke, carbonic oxide, and hydrogen. Now the results produced by both these extremes of temperature are valueless to the gas manufacturer, and it is therefore necessary to employ a heat sufficiently high to prevent as much as possible the volatile substances from escaping in the form of condensible vapors, but not high enough to decompose the luminiferous constituents of the evolved gas. If coal were a definite and single chemical compound, and could be so exposed to heat as to suddenly raise the temperature of every particle to a uniform and definite degree, it is highly probable that the results of the distillation would be far less complex than they are in the present mode of gas manufacture; and it might even be possible to find such a degree of temperature as would convert a whole coal into one or more of the higher gaseous compounds of carbon, thus giving results of maximum value to the gas-manufacturer. In the ordinary processes of gas-making, where a charge of several cwts. of coal, often in large lumps, is thrown into an ignited retort, it is impossible to attain any such uniform temperature. The heat is conducted very gradually to the interior of the mass of coal, and therefore various portions of the charge are exposed to very unequal temperatures, especially in the earlier stages of the distillation. The natural consequence of these conditions is the production, on the one hand, of products resulting from excessive temperature, viz.: hydrogen and light carburetted hydrogen, and on the other, of tar, which may be regarded as the consequence of deficient heat. Notwithstanding several attempts, these disadvantages have not yet been successfully overcome, but the importance of a practical process which would secure a tolerably uniform temperature during the whole course of distillation, is seen from the remarkable results obtained with Clegg’s revolving web retort—a form of apparatus undoubtedly the most ingenious yet invented for the production of gas, and which, although in its present form too complicated for successful practical use, yet embodies, when we consider the early date of its invention, in a remarkable manner, the true scientific principles of gas-making. This retort, of which a description will be found at p. 381, is said to a great extent to obviate the inequality and uncertainty of temperature in the ordinary gas retorts, and the result was an increase of from 30 to 40 per cent. in the quantity of gas produced, the quality being also improved, whilst scarcely any tar was formed.

But besides the great influence exerted by the temperature to which coal is exposed in the process of gas-making, the length of time, during which the volatile products of decomposition are exposed to that temperature, is a most important circumstance as regards the successful manufacture of gas. If we take into consideration the behavior of the luminiferous constituents of gas when exposed to a bright red heat, and which has been described above, it will be evident that a second most important condition in the manufacture of gas is the rapid removal of these luminiferous constituents from the destructive influence of the red-hot retort as soon as they are generated; every second during which these gases are allowed to remain in their birthplace diminishes their value as illuminating agents. The only method hitherto employed for the rapid removal of the gases from the retorts is White’s process, the mechanical details of which are fully described below. This process consists essentially in transmitting a current of water gas through the retorts in which coal or cannel gas is being generated. The water gas is produced by transmitting steam through retorts filled with coke or charcoal, and consists of a mixture of hydrogen, carbonic oxide, and carbonic acid gases. These gases, which are not in themselves luminiferous on combustion, necessarily become mixed with the coal or cannel gas, and thus diminish the illuminating power of the latter whilst they increase its volume. Nevertheless, if the admission of water gas be properly managed, the luminiferous constituents saved from destruction by the rapid removal from the retorts, compensate for the dilution of the gas, so as to render the diluted gas equal in illuminating power to the gas produced from the same coal or cannel in the ordinary process of manufacture. When cannels yielding very highly luminiferous gas are employed, it is desirable to dilute them to a much greater extent, and this can be easily effected by admitting into the coal retort a larger proportion of water gas.
some cases the total amount of light yielded by the gas from a given weight of coal when treated according to White's process is more than double that obtained by the ordinary process, and in all cases the gain in total amount of light is very large, thus showing the importance of removing the gases from the red-hot retorts as rapidly as possible. This remark applies especially to gases very rich in luminous hydrocarbons, because such gases suffer relatively much more deterioration than those containing a larger proportion of diluents. In addition to these advantages such a dilution of rich caudal gases with any of the non-luminous constituents, hydrogen, carbonic oxide, or light carburetted hydrogen, increases the illuminating power of the gas in another way: this is effected by their forming a medium for the solution of the vapors of such hydrocarbons as exist in the liquid or even solid state at the ordinary temperature of the atmosphere, and they thus enable us to convert an additional quantity of illuminating materials into the gaseous form, which they retain permanently, unless the temperature fall below the point of saturation. The gain in illuminating power which is thus obtained will be perhaps better seen from the following example:—Suppose 100 cubic inches of olefiant gas were allowed to saturate itself with the vapor of a volatile hydrocarbon, containing three times as much carbon in a given volume of its vapor as that contained in an equal volume of olefiant gas, and that it took up or dissolved 3 cubic inches of this vapor; then, if we express the value of 1 cubic inch of olefiant gas by unity, the illuminating power of the 103 cubic inches of the mixture of olefiant gas and hydrocarbon vapor will be 199. Now if we mix these 103 cubic inches with 100 cubic inches of hydrogen, the mixture will be able to take up an additional 2 cubic inches of hydrocarbon vapor, and the illuminating power of the 203 cubic inches will then become 118; thus the hydrogen produces a gain in illuminating power equal to 9 cubic inches of olefiant gas, or nearly 4.5 per cent. upon the volume of mixed gases. When we consider that coal naphtha contains hydrocarbons of great volatility, and that these are the surplus remaining after the saturation of the gas from which they have condensed, the importance of this function of the non-illuminating class of combustible gases will be sufficiently evident. It may here be remarked that incombustible gases could not be employed for this purpose, since their cooling influence upon the flame during the subsequent burning of the gas would diminish the light to a greater extent than the hydrocarbon vapor could increase it.

It is evident that all the three non-illuminating gases, forming the class of diluents, would perform both the offices here assigned to them perfectly well, and therefore we have as yet seen no reason for giving our preference in favor of any one of these diluents; if, however, we study their behavior during combustion, we shall find that where the gas is to be used for illuminating purposes, hydrogen has qualities which give it a very decided preference over the other two. When gas is used for lighting the interior of public buildings and private houses, it is very desirable that it should deteriorate the air as little as possible, or, in other words, it should consume as small a quantity of oxygen and generate as little carbonic acid as possible. The oppressive heat which is so frequently felt in apartments lighted with gas also shows the advantage of the gas generating a minimum amount of heat.

The following is a comparison of the properties of the three non-illuminating gases in reference to the points just mentioned:—

One cubic foot of light carburetted hydrogen, at 60° Fahr. and 30 inches barometrical pressure, consumes 2 cubic feet of oxygen during its combustion, and generates 1 cubic foot of carbonic acid, yielding a quantity of heat capable of heating 5 lbs. 14 oz. of water from 32° to 212°, or causing a rise of temperature from 60° to 80° in a room containing 2,500 cubic feet of air.

One cubic foot of carbonic oxide, at the same temperature and pressure, consumes, during combustion, ⅔ a cubic foot of oxygen, generates 1 cubic foot of carbolic acid, and affords heat capable of raising the temperature of 1 lb. 14 oz. of water from 32° to 212°, or that of 2,500 cubic feet of air from 60° to 66°.

One cubic foot of hydrogen, at the same temperature and pressure, consumes ⅔ a cubic foot of oxygen, generates no carbonic acid, and yields heat capable of raising the temperature of 1 lb. 13 oz. of water from 32° to 213°, or that of 2,500 cubic feet of air from 60° to 64°.

This comparison shows that light carburetted hydrogen is very objectionable as a diluent, not only on account of the carbolic acid which it generates, but also by reason of the very large quantity of oxygen which it consumes, and the very great amount of heat which, in relation to its volume, it evolves on combustion; the consumption of oxygen being four times, and the absolute thermal effect more than three times as great as that of either of the other gases.

The quantity of heat evolved by the combustion of equal volumes of carbolic oxide and hydrogen is nearly, and the amount of oxygen consumed quite, the same; but the carbolic acid evolved from the first gives a decided preference to hydrogen as the best diluent.

The same comparison also shows that when the gas is to be used for heating purposes,
and the products of combustion are carried away, light carburetted hydrogen is by far the
best diluent.

The experiments of Dulong on the absolute thermal effects of hydrogen, light carburetted
hydrogen, and carbonic oxide are taken as the basis of the foregoing calculations. Dulong found that—

1 lb. of hydrogen raised the temperature of 1 lb. of water through 6244° F.
1 lb. of carburetted hydrogen    "        "        4591° F.
1 lb. of light carburetted hydrogen    "        " 2442° F.

These considerations indicate the objects that should chiefly be regarded, in the generating
department of the manufacture of gas for illuminating purposes. They are—

1st. The extraction of the largest possible amount of illuminating compounds from a
given weight of material.

2d. The formation of a due proportion of illuminating and non-illuminating constitu-
ents, so that on the one hand the combustion of the gas shall be perfect, and without
the production of smoke or unpleasant odor, and on the other, the volume of gas required to
obtain a certain amount of light shall not be too large.

3d. The presence of the largest possible proportion of hydrogen amongst the non-illu-
minating constituents, to the exclusion of light carburetted hydrogen, and carbonic oxide; so
as to produce the least amount of heat and atmospheric deterioration in the apartments
in which the gas is consumed.

On the purification of illuminating gas.—If we except the insignificant quantities of ni-
trogen and oxygen, which become mixed with illuminating gas through imperfections in the
joints of the apparatus employed, and by the transferring power of the water of the gas-
holder, all impurities arise from the presence of the three elements sulphur, oxygen, and
nitrogen in the generating material used.

The sulphur, uniting with portions of the hydrogen and carbon of the coal, generates
with the firstnamed element sulphuretted hydrogen, and with the second, bisulphide of
carbon. It is also probable that volatile organic ammas of sulphur are produced by
the union of this element with carbon and hydrogen simultaneously, although we have as
yet no positive evidence of their presence in illuminating gas. The oxygen, uniting with
another portion of carbon, forms carbonic acid, whilst the nitrogen unites with hydrogen to
form ammonia, which, by combination with sulphuretted hydrogen, produces hydro sulphate
of sulphide of ammonium, and, with carbonic acid and water, carbonate of ammonia. With
the exception of bisulphide of carbon and the organic sulphur compounds just mentioned,
the removal of all these impurities is not difficult. Slaked lime, either in the form of moist
powder, or suspended in water as milk of lime, absorbs the whole of them; whilst it has no
perceptible effect upon the other constituents of the gas. By this process of purification
the sulphuretted hydrogen and caustic lime are converted into sulphate of calcium and
water; the former, being non-volatile, does not mix with the gas. Hydro sulphate of sulphide
of ammonium is in like manner converted into sulphate of calcium, water, and ammonia;
part of the latter is retained by the moisture present in the purifying material, but the re-
mainder mixes with the gas, from which, however, it can be removed by contact with a large
surface of water. Carbonic acid unites with caustic lime with great energy, forming car-
bonate of lime, a perfectly non-volatile material; and thus the acid gas is effectually re-
tained. Carbonate of ammonia is under similar circumstances decomposed, carbonate of
lime being formed and ammonia liberated; the last, as before, being only partially retained
by the moisture present, and requiring, when "dry-lime" is used, a subsequent application
of water for its complete removal. Although in the wet lime purifying process a given
weight of lime can remove a much larger volume of impurities, yet the dry lime process pos-
sesses so many manipulatory advantages that it is now all but universally employed where
lime is used as the purifying agent. The maximum amount of sulphuretted hydrogen or
of carbonic acid which can be absorbed by 1 lb. of quicklime in the so-called dry and wet
states respectively, is seen from the following table:—

<table>
<thead>
<tr>
<th>Cube feet of</th>
<th>Cube feet of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphuretted hydrogen</td>
<td>Carbonic acid</td>
</tr>
<tr>
<td>1 lb. of quick-lime used as dry lime absorbs</td>
<td>6.78</td>
</tr>
<tr>
<td>1 lb. of quick-lime used as wet lime absorbs</td>
<td>6.78</td>
</tr>
</tbody>
</table>

In practice, however, the absorption actually effected is, even under the most favorable
circumstances, considerably less than here indicated. As a substitute for lime in the puri-
fication of gas a mixture of hydrated peroxide of iron and sulphate of lime has lately come
into extensive use. This material is prepared in the first place by mixing slaked lime with
hydrated peroxide of iron, the composition being rendered more porous by the addition of
a certain proportion of sawdust. This mixture is now in a condition to remove those im-
purities from coal-gas which are abstracted by lime. The peroxide of iron absorbs sul-
phuretted hydrogen and sulphide of ammonium and becomes converted into sulphide of iron.
COAL-GAS.

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The slaked lime absorbs carbonic acid and carbonate of ammonia until it is converted into subcarbonate of lime. When the absorbing powers of the mixture are nearly exhausted, the covers of the purifiers are removed and the mixture is exposed to the air. The following change is then said to take place. The sulphide of iron rapidly absorbs oxygen and becomes converted first into sulphate of protoxide of iron, and finally into sulphate of peroxide, which latter is decomposed by the carbonate of lime, carbonic acid being evolved as gas, whilst sulphate of lime and peroxide of iron are produced; the mixture is thus again rendered available for the process of purification; the peroxide of iron acts as before, but in the place of quick-lime we have now sulphate of lime, which is quite effectual for the removal of carbonate of ammonia, with which it forms carbonate of lime and sulphate of ammonia; but the mixture is incapable of removing free carbonic acid, and it is therefore necessary to provide a separate dry lime-purifier for the removal of this gas. When the purifying material is again saturated with the noxious gases, another exposure to atmospheric oxygen restores it again to its active condition, the only permanent effect upon it being the accumulation of sulphate of ammonia within its pores. If this latter salt be occasionally dissolved out with water, the mixture may be used over and over again to an almost unlimited extent. It has been found that this process can be much simplified, and Mr. Hills, who has brought gas purification to great perfection, recommends that hydrated peroxide of iron should be merely mixed with a considerable bulk of sawdust and placed in the purifiers. After the gas has passed through this mixture for 18 hours, it is shut off and replaced by a current of air forced through by a faner for 6 hours. The sulphide of iron is thus oxidized, sulphur being separated and hydrated peroxide of iron regenerated; and the purifying material being now revivified, the gas may be passed through it again as before. In this way it is only found necessary to remove the material once a month in order to separate the lowest stratum of about an inch in thickness, which has become clogged up with tar. A proportional quantity of fresh mixture of hydrated peroxide of iron and sawdust having been added, the whole is again returned to the purifier. It is difficult to conceive a more simple and inexpensive process of purification than this. It does not, however, remove carbonic acid. Several other materials have been proposed for the separation of sulphuretted hydrogen from coal-gas, such as sulphate of lead, and chlorid of manganese, but they possess no peculiar advantages and have never been extensively adopted.

It has been already mentioned that, in addition to sulphuretted hydrogen and carbonic acid, which are readily removed by the processes just described, there also exist in coal-gas, as impurities, variable quantities of bisulphide of carbon and probably sulphuretted hydrocarbons. Now all these sulphur compounds produce sulphurous acid during the combustion of the gas, and where the quantities of these impurities are considerable, as is the ease with much of the gas now manufactured, the atmosphere of the apartments in which such gas is used becomes so strongly impregnated with sulphurous acid, as to be highly offensive to the senses and very destructive to art decorations, bindings of books, &c. It becomes, therefore, a matter of considerable importance to prevent, as far as possible, the occurrence of these injurious constituents; in fact, until this is effected, gas will never be more than very partially adopted as a means of illumination in dwelling-houses. When once generated with coal-gas all attempts to remove these constituents have hitherto proved ineffectual, and there seems little ground for hope that any practical process will be devised for their abatement. Attention may, therefore, more profitably be directed to the conditions which tend to diminish the amount generated in the retorts, or altogether to prevent their formation. Mr. Wright, who has paid considerable attention to this problem, finds that the employment of a moderate heat for the generation of the gas has the effect of greatly reducing the relative quantity of these noxious ingredients, and thus, by simply avoiding excessive heat in the retorts, and rejecting the last portions of gas, he has, to a great extent, prevented their formation. Unfortunately, however, this remedy is not likely to find favor amongst gas-manufacturers in general, inasmuch as it considerably reduces the yield of gas. A few well-directed chemical experiments could scarcely fail to discover the conditions necessary for the non-production of these sulphuretted compounds. Probably the proper admixture of salt or lime with the coals before carbonization would have the desired effect. The subject is one of so much importance to the future of gas illumination, that it ought not to be suffered to rest in its present unsatisfactory condition.

On the consumption of gas.—The proper consumption or burning of illuminating gas depends upon certain physical and chemical conditions, the due observance of which is of great importance in the development of a maximum amount of light. The production of artificial light depends upon the fact that, at certain high temperatures, all matter becomes luminous. The higher the temperature the greater is the intensity of the light emitted. The heat required to render matter luminous in its three states of aggregation differs greatly. Thus solids are sometimes luminous at comparatively low temperatures, as phosphene and phosphoric acids. Usually, however, solids require a temperature of 600° or 700° F. to render them luminous in the dark, and must be heated to 1000° F. before their luminos-
ity becomes visible in daylight. Liquids require about the same temperature. But to render gases luminous, they might be exposed to an immensely higher temperature; even the intense heat generated by the oxyhydrogen blowpipe scarcely suffices to render the aqueous vapor produced visibly luminous, although solids, such as lime, emit light of the most dazzling splendor when they are heated in this flame. Hence those gases and vapors only can illuminate which produce, or deposit, solid or liquid matter during their combustion. This dependence of light upon the production of solid matter is strikingly seen in the case of phosphorus, which when burnt in chlorine produces a light scarcely visible, but when consumed in air or oxygen emits light of intense brilliancy. In the former case the vapor of chloride of phosphorus is produced, in the latter, solid phosphoric acid.

Several gases and vapors possess this property of depositing solid matter during combustion, but a few of the combinations of carbon and hydrogen are the only ones capable of practical application: these latter compounds evolve during combustion only the same products as those generated in the respiratory process of animals, viz.: carbonic acid and water. The solid particles of carbon which they deposit in the interior of the flame, and which are the source of light, are entirely consumed on arriving at its outer boundary; their use as sources of artificial light, under proper regulations, is therefore quite compatible with the most stringent sanitary rules.

The constituents of purified coal-gas have already been divided into illuminating and non-illuminating gases; amongst the latter will be found light carburetted hydrogen, which, although usually regarded as an illuminating gas, has been proved by the experiments of Frankland to produce, under ordinary circumstances, no more light than hydrogen or carbonic oxide, and therefore for all practical purposes it must be regarded as entirely destitute of illuminating power. This is owing chiefly to the temperature required for the deposition of its carbon being higher than that attained in an ordinary gas-burner; for Frankland has proved that, if the temperature of the light carburetted hydrogen flame be increased by previously heating the gas and air nearly to redness, then the flame becomes luminous to a considerable degree. It is not improbable that when gas is consumed in very large burners the necessary temperature is attained, and the light carburetted hydrogen contributes considerably to the aggregate illuminating effect; a view which is, to a certain extent, confirmed by the fact, that a relatively much larger amount of light is obtained from coal-gas when the latter is consumed in a large flame than when it is allowed to burn in a small flame.

Omitting light carburetted hydrogen and carbonic oxide, the remaining carboniferous constituents of coal-gas yield, during combustion from suitable burners, an amount of light directly proportionate to the quantity of carbon which they contain in a given volume.

In order to understand the nature of the combustion of a gas flame, it is necessary to remember that the flame is freely permeable to the air, and that, according to the well-known laws of gaseous mixture, the amount of air which mixes with the ignited gases will be increased, first, by an increase of the velocity with which the gas issues from the orifice of the burner; and secondly, by the velocity of the current of air immediately surrounding the flame. It is well known that a highly luminous gas may be deprived of all illuminating power either by being made to issue from the burner with great velocity, or by being burnt in a very rapid current of air produced by a very tall glass chimney.

The foregoing considerations indicate the conditions best adapted for obtaining the maximum illuminating effect from coal-gas. The chief condition is the supply of just such a volume of air to the gas flame as shall prevent any particles of carbon from escaping unconsumed. Any excess of air over this quantity must diminish the number of particles of carbon deposited within the flame, and consequently impair the illuminating effect.

Another condition is the attainment of the highest possible temperature within the flame. The first of these conditions has been more or less perfectly obtained in the different gas-burners now in use. The second has been hitherto almost entirely neglected: the means by which it may be attained will be discussed after the burners at present in general use have been described.

The chief burners now in use are the bat's-wing, fish-tail, argand, bude argand, Winfield's argand, Guise's argand, and Leslie's argand.

The bat's-wing consists of a fine slit in an iron nipple, giving a flat fan-like flame.

The fish-tail consists of a similar nipple perforated by two holes, drilled so that the jets of gas are inclined towards each other at an angle of about 60°. A flat film of flame is thus produced, somewhat resembling the tail of a fish. This form of burner is especially adapted for the consumption of camell and other highly illuminating gases.

The argand consists of a hollow annulus (see Fig. 101,) from the upper surface of which the gas issues through a number of small apertures, which are made to vary in diameter from \( \frac{1}{10} \) of an inch to \( \frac{1}{10} \) of an inch, according to the richness of the gas; the most highly illuminating gases requiring the smallest apertures. The distances of the orifices for coal-
gas should be 16 to 18 inch, and for rich cannel gas 13 inch. If the argand ring has ten orifices, the diameter of the central opening should be \( \frac{1}{16} \) of an inch; if 25 orifices, it should be 1 inch for coal gas; but for oil gas, with 10 orifices, the central opening should have a diameter of \( \frac{1}{3} \) an inch, and for 20 orifices, 1 inch. The pin holes should be of equal size, otherwise the larger ones will cause smoke, as in an argand flame with an uneven wick.

The bod burners consist of 2 or 3 concentric argand rings perforated in the manner just described. It is well adapted for producing a large body of very intense light with a comparatively moderate consumption of gas.

Winfield's argand.—The chief distinction between this and the ordinary argand burner consists in the introduction of a metallic button above the annulus, so as to cause the internal current of air to impinge against the flame. A peculiarity in the shape of the glass chimney, as seen in the figure, produces the same effect upon the outer current of air. See fig. 162.

Guise's argand contains 26 holes in a ring, the inner diameter of which is 6 inch, and the outer diameter 1\( \frac{3}{4} \) inch. Like the Winfield burner, it has a metal button \( \frac{1}{4} \) an inch in diameter, and 1 inch above the annulus. The glass chimney, which is cylindrical, is 2 inches in diameter, and 6 inches long.

Leslie's argand consists, as is seen in the figure, (fig. 164,) of a series of fine tubes arranged in a circle, by which a more uniform admixture of air with the gas is effected. A sufficient current of air for all these argand burners can only be obtained by the use of a glass chimney, the rapidity of the current depending upon the height of the chimney. In the Leslie's argand the height of the chimney is especially adapted to the amount of light required, and in order to consume gas economically, this point must be attended to in all argand burners.

The following experiments made with different burners, by three eminent experimenters, upon the gas from three different kinds of coal, show the relative values of these burners for the gases produced from the chief varieties of coal used for the manufacture of gas in this country.

**Table 1.—Results of Experiments on Newcastle Cannel Gas, by Mr. A. Wright.**

<table>
<thead>
<tr>
<th></th>
<th>1 Foot per Hour</th>
<th>1( \frac{1}{2} ) Foot per Hour</th>
<th>2 Feet per Hour</th>
<th>2( \frac{1}{2} ) Feet per Hour</th>
<th>3 Feet per Hour</th>
<th>3( \frac{1}{2} ) Feet per Hour</th>
<th>4 Feet per Hour</th>
<th>4( \frac{1}{2} ) Feet per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotch Fish-tail, No. 1:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot = candles *</td>
<td>475</td>
<td>552</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot = grains of sperm</td>
<td>585</td>
<td>605</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Scotch Fish-tail, No. 3:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot = candles *</td>
<td>595</td>
<td>657</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>One foot = grains of sperm</td>
<td>606</td>
<td>690</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Guise's Argand:</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot = candles *</td>
<td>108</td>
<td>115</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot = grains of sperm</td>
<td>129</td>
<td>229</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = = grains of sperm
Table II.—Experiments on Wigan Cannel Gas, at different Rates of Consumption, by Mr. Alfred King.

<table>
<thead>
<tr>
<th>Source of Gas</th>
<th>4 Foot.</th>
<th>1 Foot</th>
<th>½ Foot</th>
<th>2 Feet.</th>
<th>2½ Feet.</th>
<th>3 Feet.</th>
<th>3½ Feet.</th>
<th>4 Feet.</th>
<th>4½ Feet.</th>
<th>5 Feet.</th>
<th>5½ Feet.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Jet:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>2.15</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>253.3</td>
<td>311.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lancashire Fish-tail,</td>
<td>1.78</td>
<td>2.18</td>
<td>1.76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>214.1</td>
<td>262.5</td>
<td>211.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lancashire Fish-tail, No. 1:</td>
<td>1.76</td>
<td>2.65</td>
<td>2.55</td>
<td>2.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>211.3</td>
<td>317.9</td>
<td>306.5</td>
<td>303.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lancashire Fish-tail, No. 2:</td>
<td>2.26</td>
<td>3.11</td>
<td>3.5</td>
<td>3.76</td>
<td>3.79</td>
<td>3.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>271.3</td>
<td>373.3</td>
<td>432.0</td>
<td>455.7</td>
<td>443.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lancashire Fish-tail, No. 3:</td>
<td>2.26</td>
<td>3.48</td>
<td>3.86</td>
<td>4.07</td>
<td>4.18</td>
<td>4.1</td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>285.5</td>
<td>419.5</td>
<td>484.4</td>
<td>556.7</td>
<td>539.9</td>
<td>530.1</td>
<td>516.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bat's wing:</td>
<td>1.83</td>
<td>3.01</td>
<td>3.73</td>
<td>4.1</td>
<td>4.12</td>
<td>4.31</td>
<td>4.3</td>
<td>4.46</td>
<td>4.42</td>
<td>4.42</td>
<td>4.4</td>
</tr>
<tr>
<td>One foot =</td>
<td>220.0</td>
<td>361.6</td>
<td>448.3</td>
<td>492.3</td>
<td>494.8</td>
<td>578.1</td>
<td>516.2</td>
<td>535.1</td>
<td>519.0</td>
<td>528.9</td>
<td></td>
</tr>
<tr>
<td>Sixteen-hole Argand, small holes in ring 0.82 inch in diameter:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>0.323</td>
<td>1.02</td>
<td>1.9</td>
<td>2.6</td>
<td>3.27</td>
<td>3.72</td>
<td>3.84</td>
<td>3.96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>38.76</td>
<td>123.3</td>
<td>228.7</td>
<td>313.0</td>
<td>333.3</td>
<td>446.4</td>
<td>461.7</td>
<td>479.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winfield's 28-hole Argand, registered July 24, 1848, with slightly conical chimney:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>0.344</td>
<td>1.16</td>
<td>2.36</td>
<td>2.71</td>
<td>3.5</td>
<td>3.72</td>
<td>3.84</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>41.27</td>
<td>139.1</td>
<td>271.3</td>
<td>325.6</td>
<td>420.5</td>
<td>446.4</td>
<td>461.7</td>
<td>481.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winfield's 58-hole Luecent Argand, registered March 29, 1845:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>0.318</td>
<td>0.75</td>
<td>1.09</td>
<td>1.57</td>
<td>2.09</td>
<td>2.59</td>
<td>3.07</td>
<td>3.82</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One foot =</td>
<td>38.2</td>
<td>87.5</td>
<td>131.8</td>
<td>188.4</td>
<td>251.1</td>
<td>311.3</td>
<td>368.9</td>
<td>458.8</td>
<td>540.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table III. contains the results of Mr. Barlow's experiments on gas produced from a mixture of Pelton, Felling, and Dean's Primrose, all first-class Newcastle gas-coals, largely used in London.

The burners employed in these experiments were the following:—
1st. A No. 3 fish-tail, or union jet.
2d. A No. 5 bat's-wing.
3d. A common argand, with 15 large holes in a ring 35 inch diameter, and a cylindrical chimney glass 7 inches high.
4th. A Platon's registered argand, with large holes in a ring, 9 inch, with inside and outside cone, and cylindrical chimney glass 8 3/2 inches high.
5th. A Binner's patent No. 3 argand, with 28 medium-sized holes in a ring 75 inch diameter, and cylindrical chimney glass 8 65 inches high.
6th. A Windfield's registered argand, with 58 medium-sized holes in 2 rings of 29 holes in each, the mean diameter being 1 inch, with deflecting button inside and gauge below, bellied chimney glass 8 inches high.
7th. A Leslie's patent argand, with 28 jets in a ring 95 inch diameter, and chimney glass 3 3/5 inches high.
8th. A Gulse's registered shadowless argand, with 26 large holes in a ring 85 inch diameter, and deflecting button, cylindrical chimney glass 6 1 inches high, and glass reflecting cone to outside gallery.

On an average of numerous trials the annexed results were obtained:—

<table>
<thead>
<tr>
<th>Burner</th>
<th>Rate of Consumption per Hour in Cubic Feet</th>
<th>Value of Cubic Foot in Grains of Sperm.</th>
<th>Standard Candles per Cubic Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 3</td>
<td>4 9</td>
<td>289 0</td>
<td>2 4</td>
</tr>
<tr>
<td>4</td>
<td>5 5</td>
<td>343 0</td>
<td>2 85</td>
</tr>
<tr>
<td>5</td>
<td>5 5</td>
<td>374 0</td>
<td>2 11</td>
</tr>
<tr>
<td>6</td>
<td>5 5</td>
<td>387 0</td>
<td>2 8</td>
</tr>
<tr>
<td>8</td>
<td>5 5</td>
<td>350 0</td>
<td>2 2 9</td>
</tr>
<tr>
<td>2</td>
<td>5 5</td>
<td>276 0</td>
<td>2 3</td>
</tr>
<tr>
<td>3</td>
<td>5 5</td>
<td>290 0</td>
<td>2 9</td>
</tr>
<tr>
<td>4</td>
<td>5 5</td>
<td>314 0</td>
<td>2 4</td>
</tr>
<tr>
<td>5</td>
<td>5 5</td>
<td>348 0</td>
<td>2 9</td>
</tr>
<tr>
<td>6</td>
<td>5 5</td>
<td>335 0</td>
<td>3 16</td>
</tr>
<tr>
<td>7</td>
<td>5 5</td>
<td>369 0</td>
<td>2 7 9</td>
</tr>
<tr>
<td>8</td>
<td>5 5</td>
<td>364 0</td>
<td>3 0 7</td>
</tr>
</tbody>
</table>

It has been stated that one of the conditions necessary for the production of the maximum illuminating power from a gas flame, is the attainment of the highest possible temperature, and that this condition has been almost entirely neglected in the burners hitherto in use. Dr. Frankland has, however, proved, by some hitherto unpublished experiments, that this condition may be easily secured by employing the waste heat radiating from the gas flame, for heating the air previous to its employment for the combustion of the gas; and that the increased temperature thus obtained has the effect of greatly increasing the illuminating power of a given volume of the gas. Fig. 165 shows the burner contrived by Dr. Frankland for this purpose. a is a common argand burner, or better, a Leslie's argand, furnished with the usual gallery and glass chimney b, c; the latter must be 4 to 6 inches longer than usual. d d is a circular disc of plate glass, perforated in the centre, and fixed upon the stem of the burner about 1/8 inches below the gallery by the collar and screw e. f f is a second glass chimney somewhat conical, ground at its lower edge so as to rest air-tight, or nearly so, upon the plate d d; and of such a diameter as to leave an annular space 1/2 inch broad between the two cylinders a g. The cylinder f should be of such a length as to reach the level of the apex of the flame. The action of this burner will now be sufficiently evident. When lighted, atmospheric air can only reach the flame by passing downwards through the space between the cylinders f and c; it thus comes into contact with the intensely heated walls of e, and has its temperature raised to about 500° or 600° before it reaches the gas flame. The passage of this heated air over the upper portion of the argand burner, also raises the temperature of the gas considerably before it issues from the burner.
Thus the gases taking part in the combustion are highly heated before inflammation, and the temperature of the flame is consequently elevated in a corresponding degree. Experiments with this burner prove a great increase in light, due chiefly to the higher temperature of the radiating particles of carbon; but, no doubt, partly also to the heat being sufficiently high to cause a deposition of carbon from the light carburetted hydrogen; thus rendering this latter gas a contributor to the total illuminating effect; whilst, when burnt in the ordinary manner, it merely performs the functions of a diluent. The following are the results of Dr. Frankland’s experiments with this burner:

<table>
<thead>
<tr>
<th>Rate of Consumption per Hour</th>
<th>Light in Sperma Candles, each burning 120 grs. per Hour.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Argand burner without external cylinder.</td>
<td></td>
</tr>
<tr>
<td>3'3 cubic feet</td>
<td>13'0 candles.</td>
</tr>
<tr>
<td>3'7 &quot;</td>
<td>15'2 &quot;</td>
</tr>
<tr>
<td>4'2 &quot;</td>
<td>17'0 &quot;</td>
</tr>
<tr>
<td>2'2 &quot;</td>
<td>13'0 &quot;</td>
</tr>
<tr>
<td>2'6 &quot;</td>
<td>15'5 &quot;</td>
</tr>
<tr>
<td>2'7 &quot;</td>
<td>16'7 &quot;</td>
</tr>
<tr>
<td>3'0 &quot;</td>
<td>19'7 &quot;</td>
</tr>
<tr>
<td>3'3 &quot;</td>
<td>21'7 &quot;</td>
</tr>
</tbody>
</table>

These results show that the new burner, when compared with the ordinary argand, saves on an average 49 per cent. of gas, when yielding an equal amount of light; and also that it produces a gain of 67 per cent. in light for equal consumptions.

Faraday’s ventilating burner.—This admirable contrivance, the invention of Mr. Faraday, completely removes all the products of combustion, and prevents their admixture with the atmosphere of the apartments in which the gas is consumed. The burner consists of an ordinary argand, fig. 106, a, fitted with a second wider and taller cylinder, c c, rests upon the outer edge of the gallery which closes at bottom the annular space, d d, between the two glass cylinders. e e is closed at top with a double mica cap e. f is the tube conveying the gas to the argand; g g is a wider tube 13 inches in diameter, communicating at one extremity with the annular space between the two glass cylinders, and at the other, either with a flue or the open air. The products of combustion from the gas flame are thus compelled to take the direction indicated by the arrows, and are therefore prevented from contaminating the air of the apartment in which the gas is consumed. h is a ground glass globe enclosing the whole arrangement, and having only an opening below for the admission of air to the flame. In order to dispense with the descending tube, to which there are some objections, Mr. Rutter has constructed a ventilating burner in which the ordinary glass chimney is made to terminate in a metal tube, through which the products of combustion are conveyed away. Mr. Dixon has also constructed a modification of Faraday’s burner, the peculiarity of which consists in the use of a separate tube bringing air to the flame from the same place, outside the building, to which the products of the burner are conveyed; this contrivance is said to prevent downward draughts through the escape pipe, and a consequently unsteady flame. Faraday’s burner is in use at Buckingham Palace, Windsor Castle, the House of Lords, and in many public buildings.

On the Estimation of the Value of Illuminating Gas.

There are two methods in use for estimating the illuminating value of gas, viz.:

1st. The photometric method.

2d. Chemical analysis.

The photometric method consists in comparing the intensity of the light emitted by a gas flame, consuming a known volume of gas, with that yielded by some other source of light taken as a standard. The standard employed is usually a spermaceti candle, burning at the rate of 120 grains of spermaceti per hour. A spermaceti candle of six to the pound usually burns at a somewhat quicker rate than this; but in all cases the consumption of spermaceti during the course of each experiment ought to be carefully ascertained by weighing, and the results obtained corrected to the 120-grain standard. Thus, suppose that during an experiment the consumption of spermaceti was at the rate of 130 grains per
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hour, and that the gas flame being tested gave a light equal to 20 such candles, and it is required to know the light of this flame in standard 120-grain candles, then—

\[ 120 : 180 : : 20 : 21.7 ; \]

or, 20 candles burning at the rate of 130 grains per hour, are equal to 21.7 candles burning at the rate of 120 grains per hour.

There are two methods of estimating the comparative intensity of the light of the gas and candle flames, both founded upon the optical law that the intensity of light diminishes in the inverse ratio of the square of the distance from its source. Thus, if a sheet of writing paper be held at the distance of one foot from a candle, so that its surface is perpendicular to a line joining the centre of the sheet and the flame, it will be illuminated with a light four times as intense as that which would fall upon a sheet of paper held in the same position at a distance of 2 feet; whilst at a distance of 3 feet the light would have but \( \frac{1}{9} \) of the intensity it possessed at 1 foot. One method of estimating the comparative intensity of the gas and candle flames, consists in placing the two lights and an opaque rod nearly in a straight line, and in such a way as to cause each light to project a shadow of the rod upon a white screen placed at a distance of about 1 foot behind the rod. The two shadows must now be rendered of equal intensity by moving the candle either nearer to the rod or further from it. The shadows will be of equal intensity when the light falling upon the white screen from both sources is equal; and if now the respective distances of the candle and gas flame from the screen be measured, then the square of the distance of the gas flame divided by the square of the distance of the candle will give the illuminating power of the gas in candles. Thus, if equally intense shadows fall upon the screen when the candle is 3 feet distant and the gas flame 12 feet, the illuminating power of the gas flame will be—

\[ \frac{12^2}{3^2} = \frac{144}{9} = 16 \text{ candles.} \]

This method of estimating the illuminating power of a gas flame, known as the shadow test, is very easy of execution, and would appear from the description to be capable of yielding results of considerable accuracy; nevertheless, an unexpected difficulty arises from the great difference in color of the two shadows; that of the gas being of a bluish brown, whilst that of the candle is of a yellow brown tinge. This difference of tint renders it exceedingly difficult for the observer to ascertain when the two shadows possess equal intensity; and, consequently, the limits of error attending determinations by this test are probably, even in the hands of an experienced operator, never less than 5 per cent., and frequently even as much as 10 per cent. The shadow test has, therefore, been all but superseded by the Brown's Photometer, which consists of a graduated metal or wooden rod about 8 or 10 feet long, and sufficiently strong to be inflexible. At one extremity of this rod is placed the gas flame, and at the opposite end the standard candle. A stand which slides easily along the rod supports a small circular paper screen, at the same height as the two flames, and at right angles to the rod. This screen consists of colorless, moderately thin writing paper, saturated with a solution of spermaceti in spirit of turpentine, except a spot in the centre, about the size of a shilling, which is to be left untouched by the solution. The spirit of turpentine soon evaporates, and the paper is now ready for use. Being more transparent in the portion which has been saturated with the spermaceti solution, it becomes a delicate test of equality of light when placed between two luminous bodies; for if the light of one of the bodies impinges with greater intensity upon one side of the screen than the other light does upon the opposite side, the difference in the transparency of the two portions of the screen will become distinctly visible; the spot in the centre appearing comparatively opaque on the less illuminated side. When the screen is brought into such a position between the two sources of light as to render the central spot nearly or quite invisible on both sides, the illuminating effect of both lights at that point may be regarded as equal; and all that now remains to be done is to measure the respective distances of the candle and gas from the screen, and divide the square of the distance of the gas by the square of that of the candle: the quotient expresses the illuminating power of the gas in candles. One of the most convenient forms of this instrument has been contrived by Mr. Wright, and may be had at 55 Millbank Street, Westminster. It consists of the following parts:—

1. A wooden rod exactly 100 inches long (p. 167) from the centres of sockets at its ends a b.
2. An upright pillar c.
3. A candle holder d.
4. A mahogany slide e, having a metal socket f on its top, to hold the circular frame g, and a small pointer in its front.
5. A circular metal frame g, used to hold a prepared paper.
6. A blackened conical screen h, diminishing in size from its centre, where it opens with a hinge towards its ends, with two holes in front.

The long rod is graduated, in accordance with the laws of distribution of light, from its

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centre each way into squares of distances in divisions numbered respectively 1, 2, 3, &c., to 36; to measure smaller differences than those amounting to 1 candle in value, each major division to 9 is subdivided into 10 parts, each, of course, representing \( \frac{1}{10} \) of an increment. From thence to 26 the subdivisions indicate \( \frac{1}{2} \). Beyond that point no subdivisions are made, because the major divisions become so small that, practically, such divisions would be useless.

The manner of fitting the apparatus together will be understood by reference to the annexed sketch.

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The pillar c is screwed to one end of the shelf, and an experimental meter i, placed at the other. This latter instrument is for measuring the quantity of gas passing to the burner, and indicating the rate of consumption by observations of one minute, which is accomplished by the construction of its index dial.

This dial has two circles upon its face, with a pointer to each; the outer circle divided into four, and the inner into six parts; and each of these again divided into tenths. Every major division of the outer circle is a cubic foot; and every major division of the inner circle is \( \frac{1}{2} \) of a cubic foot; so that the major divisions on the inner circle each bear the same proportion to a cubic foot that a minute does to an hour. If, therefore, the number of these divisions and tenths of divisions, which the hand passes over in a minute, is observed, it will evidently only be necessary to read them off as feet and tenths of a foot to obtain the hourly rate of consumption.

Thus, suppose the pointer passes from the upper figure 6 to the fifth minor division beyond the figure 4, it would read off as \( 4\frac{1}{10} \) and \( \frac{5}{60} \) of a cubic foot in \( \frac{1}{60} \) of an hour. Multiplying these quantities by 60, we have \( \frac{1}{60} \times 60 = \frac{60}{60} = 4\frac{1}{2} \) cubic feet and \( \frac{60}{60} = 1 \); so that 4 1/2 feet and 1 hour are obtained by simply reading off the divisions which had been passed as feet and tenths.

A pillar j, having a pressure gauge and two cocks at k, one with a micrometer movement, screws on to the top of the meter, and is intended for receiving burners when experimenting. The graduated rod is supported in an exactly horizontal position by the pillars c and x, and screwed together by its binding screws.

The candle socket n is screwed on to the top of c, and the mahogany slide i placed on the rod, with its pointer to the scale, carrying the frame o, containing a prepared paper, and covered by the cone p.

The prepared paper is made by coating white blotting-paper with sperm, so as to render it semi-transparent, leaving a small spot in the centre plain, and therefore opaque. See \( \alpha \) in the figure.

All that now remains to render the apparatus ready for experimenting, is to put a piece of candle into the socket, and consume the gas through a proper burner over the meter, taking care that the centres of the candle-flame, paper, and gas flame, are in one horizontal line, and adopting the precautions previously laid down.

Unfortunately, the determination of the exact point of equality of the two lights is by no means easy, even after considerable practice; and the maximum amount of error to which even the practised operator is liable in such estimations of illuminating power, cannot be set down at less than 5 per cent. It is scarcely necessary to add, that all photometric experiments must be conducted in an apartment from which all light from other sources is excluded, and the walls of which are rendered as absorbent as possible, by being coated with a mixture of lampblack and size, or by being hung with black lustreless curtains.

Analytical Method of Estimating the Value of Illuminating Gas.—Frankland has shown that the resources of chemical analysis place in our hands a method for the determination of the illuminating value of gas considerably more accurate than the photometric processes just described, although the execution of the necessary operations requires more skill, and is usually much more troublesome. As the determination of the illuminating power of a sample of gas by the analytical method necessitates most of the operations required for the performance of a complete analysis of coal-gas, we shall here include in our description of the former process the additional details necessary for the latter.
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1. Collection of the Sample of Gas.—In all analytical operations upon gases, it is of the utmost importance that the latter should be preserved from all admixture with atmospheric air. This can only be done, either by collecting the samples of gas over mercury, or by enclosing them in hermetically sealed tubes. When the sample of gas is collected at the place where the analysis is to be made, the former plan is usually most convenient; but when the sample has to be obtained from a locality at some distance from the operator’s laboratory, the latter plan is usually adopted. To collect a sample of gas over mercury, attach one end of a piece of vulcanized India-rubber tube to the gas-pipe, and insert into the other extremity a piece of glass tube bent, as shown at $\lambda$, fig. 168, allow the gas to stream through these tubes for two or three minutes, and then suddenly plunge the open extremity of the glass tube beneath the surface of the mercury in the trough $c$. Then fill the small glass jar $\alpha$ completely with mercury, taking care to remove all air-bubbles from its sides by means of a piece of iron wire, and closing its mouth firmly with the thumb, invert it in the trough $c$, introducing the end of the bent tube $\lambda$ into its open extremity, in such a way as to bring the mouth of $\lambda$ above the level of the surface of the mercury in $c$. The gas will then flow into $\alpha$, until the level of the mercury in $\alpha$ is somewhat lower than that of the metal in the trough.

If now, the tube $\lambda$ being removed, a small cup be filled with mercury and brought beneath $\alpha$, the latter may be removed from the trough, and will be thus preserved from any appreciable atmospheric intermixture for several months.

To collect samples of gas in hermetically sealed tubes, proceed as follows: Take a piece of glass tube about $\frac{1}{2}$ of an inch internal diameter, and 1 foot long; draw it out at both ends before the blowpipe, as shown in fig. 169; attach one extremity $\alpha$, fig. 170, to a vulcanized India-rubber tube, communicating with a source of the gas, and the opposite extremity $\beta$ to a similar flexible tube about three feet long, and which is allowed to hang down perpendicularly from $\beta$. After the gas has streamed through this system of tubes for about three minutes, so as to ensure the complete expulsion of atmospheric air, the flame of a mouth blowpipe is directed against the narrow portion of the glass tube at $\beta$, so as to fuse it off. With as much expedition as possible the same operation is performed at the opposite extremity of the tube $d$, which is thus hermetically sealed, and assumes the appearance shown in fig. 171.

The gas having been thus carefully collected, the necessary analytical operations must be conducted over mercury in a small wooden pneumatic trough, with plate glass sides, the construction of which is shown in fig. 172. $\alpha$ is a piece of hard well-seasoned wood, 12 inches long and 8 inches broad, hollowed out, as shown in the figure; the cavity is $\frac{7}{8}$ inches long, $\frac{1}{2}$ inches broad, and $\frac{1}{2}$ inches deep. The bottom of this cavity is rounded, with the exception of a portion at one end, where a surface, 1 inch broad, and $\frac{1}{2}$ inches long, is made posteriad, the piece of vulcanized India-rubber tube of an inch thong, being firmly cemented upon it. Two end pieces $\alpha \beta$, $\frac{4}{2}$ of an inch thick, $\frac{3}{2}$ inches broad, and 5 inches high, are fixed to the block $\alpha$; these serve below as supports for $\lambda$, and above as the ends of a wider trough, which is formed by the pieces of plate glass $\alpha \beta \gamma$, cemented into $\lambda$ and $\alpha \beta$. The glass plates $\alpha \beta \gamma$ are 10$\frac{1}{2}$ inches long, and 1$\frac{1}{2}$ inches high; they are slightly
inclined, so that their lower edges are about \( \frac{3}{4} \) inches, and their upper edges \( \frac{1}{2} \) inches apart. This trough stands upon a wooden slab \( ab \), upon which it is held in its place by two strips of wood \( cd \). An upright column \( r \), which is screwed into \( b \), carries the inclined stand \( a \), which serves to support the eudiometer during the transference of gas. \( h \) is a circular inclined slot in \( n \), which allows of the convenient inclination of the eudiometer in the stand \( g \). \( i \) is an indentation in which the lower end of the eudiometer rests, so as to prevent its falling into the deeper portion of the trough \( A \). When in use, the trough is filled with quicksilver to within an inch of the upper edge of the glass plates \( cd \), about 30 to 35 lbs. of the metal being necessary for this purpose.

The eudiometers, or measuring tubes, should be accurately calibrated and graduated into cubic inches and tenths of a cubic inch, the tenths being subdivided by the eye into hundredths, when the volume of gas is read off; this latter division is readily attained by a little practice. At each determination of volume, it is necessary that the gas should either be perfectly dry, or quite saturated with moisture. The first condition is attained by placing in the gas, for half an hour, a small ball of fused chloride of calcium, attached to a platinum wire; the second condition, by introducing a minute drop of water into the head of the eudiometer, before filling it with quicksilver. The determinations of volume must either be made when the mercury is at the same level inside and outside the eudiometer, or, as is more frequently done, the difference of level must be accurately measured and allowed for in the subsequent reduction to a standard pressure. The height of the barometer and the temperature of the surrounding atmosphere must also be observed each time the volume of gas is measured, and proper corrections made for pressure, temperature, and also the tension of aqueous vapor, if the gas be moist. As tables and rules for these corrections are given in most treatises on chemistry, they need not be repeated here.

These troublesome corrections and calculations can be avoided, by employing an instrument lately invented by Dr. Frankland and Mr. Ward, and which not only does away with the necessity for a room devoted exclusively to gaseous manipulations, but greatly shortens and simplifies the whole operation. This instrument, which is represented by fig. 173, consists of the tripod \( a \), furnished with the usual levelling screws, and carrying the vertical pillar \( ab \), to which is attached, on the one side, the movable mercury trough \( c \), with its rack and pinion \( e, a \), and on the other, the glass cylinder \( b, n \), with its contents. This cylinder is 36 inches long, and 4 inches internal diameter; its lower extremity is firmly cemented into an iron collar \( e \), the under surface of which can be screwed perfectly water-tight upon the bracket-plate \( d \) by the interposition of a vulcanized caoutchouc ring. The circular iron plate \( d \) is perforated with three apertures, into which the caps \( c, e, g \), are screwed, and

These balls, which should be of the size of a large pea, are required constantly in operations upon gases; they are readily prepared, when the substance of which they are formed is fusible by heat, as chloride of calcium or caustic potash, by melting these materials in a crucible and then pouring them into a small bullet-mould in which the curved end of a platinum wire has been placed; when quite cold the foil attached to the wire is readily removed from the mould. Coke bullets are made by filling the mould containing the platinum wire with a mixture of two parts of coke and one of coal, both finely powdered, and then exposing the mould and its contents to a heat gradually increased to redness, for a quarter of an hour.
which communicate below the plate with the tube e. This latter is furnished with a double-way cock f, and a single-way cock g, by means of which the tubes cemented into the sockets e, e, e, can be made to communicate with each other, or with the exit pipe h at pleasure.

f, g, h, are three glass tubes, which are firmly cemented into the caps e, e, e. F and h are each from 15 to 20 millimetres internal diameter, and are selected of as nearly the same bore as possible, to avoid a difference of capillary action. The tube e is somewhat wider, and may be continued to any convenient height above the cylinder. h is accurately graduated with a millimetre scale, and is furnished at top with a small funnel i, into the neck of which a glass stopper, about 2 millimetres in diameter, is carefully ground. The tube f terminates at its upper extremity in the capillary tube k, which is carefully cemented into the small steel stopcock l. f has also fused into it at m, two platinum wires, for the passage of the electric spark. After this tube has been firmly cemented into the cap e, its internal volume is accurately divided into 10 perfectly equal parts, which is effected without difficulty by first filling it with mercury from the supply tube o, up to its junction with the capillary attachment, and then allowing the mercury to run off through the nozzle k until the highest point of its convex surface stands at the division 10, previously made so as exactly to coincide with the zero of the millimetre scale on h; the weight of the mercury thus run off is carefully determined, and the tube is again filled as before, and divided into 10 equal parts, by allowing the mercury to run off in successive tenths of the entire weight, and marking the height of the convexity after each abstraction of metal. By using the proper precautions with regard to temperature, &c., an exceedingly accurate calibration can, in this way, be accomplished.

The absorption tube i is supported by the clamp n, and connected with the capillary tube k, by the stopcock and junction piece i f, p, as shown in the figure. When the instrument is thus far complete, it is requisite to ascertain the height of each of the nine upper divisions on the tube, above the lowest or tenth division. This is very accurately effected in a few minutes by carefully levelling the instrument, filling the tube o with mercury, opening the cock l, and the stopped funnel i, and placing the cock f in such a position as to cause the tubes f h to communicate with the supply tube o. On now slightly turning the cock g, the mercury will slowly rise in each of the tubes f and h; when its convex surface exactly coincides with the ninth division on f, the influx of metal is stopped, and its height in h accurately observed; as the tenth division on f corresponds with the zero of the scale upon h, it is obvious that the number thus read off is the height of the ninth division above that zero point. A similar observation for each of the other divisions upon f completes the instrument.

Before using the apparatus, the large cylinder d p is filled with water, and the internal walls of the tubes f and h are, once for all, moistened with distilled water, by the introduction of a few drops into each, through the stopcock l, and the stopped funnel i. The three tubes being then placed in communication with each other, mercury is poured into o until it rises into the cup i, the stopper of which is then firmly closed. When the mercury begins to flow from l, that cock is also closed. The tubes f and h are now apparently filled with mercury, but a minute and imperceptible film of air still exists between the metal and

* This instrument may be obtained from Mr. Oertling, philosophical instrument-maker, 261 Street Tottenham Court Road.
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glass; this is effectively got rid of by connecting r and w with the exit tube A, and allowing the mercury to flow out, until a vacuum of several inches in length has been produced in both tubes; on allowing the instrument to remain thus for an hour, the whole of the film of air above mentioned will diffuse itself into the vacuum, to be filled up from the supply tube e. These bubbles are of course easily expelled on momentarily opening the cock a and the stopper i whilst o is full of mercury. The absorption tube i being then filled with quicksilver, and attached to l by the screw clamp, the instrument is ready for use.

In illustration of the manner of using the apparatus, a complete description of an analysis of coal-gas by this instrument will be given below.

For the analysis of purified coal-gas by means of the mercury trough and endiometer, the following operations are necessary:—

I. Estimation of Carbonic Acid.

A few cubic inches of the gas are introduced into a short endiometer, moistened as above described; the volume is accurately noted, with the proper corrections, and a bullet of caustic potash is then passed up through the mercury into the gas; it is allowed to remain for at least one hour; the volume of the gas, being again ascertained and subtracted from the first volume, gives the amount of carbonic acid which has been absorbed by the potash.

II. Estimation of Oxygen.

This gas can be very accurately estimated by Liebig's method, which depends upon the rapid absorption of oxygen by an alkaline solution of pyrogallic acid. To apply this solution, a small test tube is filled with quicksilver, and inverted in the mercury trough; a few drops of a saturated solution of pyrogallic acid in water are thrown up into this tube by means of a pipette, and then a similar quantity of a strong solution of potash; a coke bullet attached to a platinum wire is introduced into this liquid, and allowed to saturate itself; it is then withdrawn, and conveyed carefully below the surface of the mercury into the endiometer containing the residual gas of experiment No. 1; every trace of oxygen will be absorbed in a few minutes, when the bullet must be removed, and the volume being again measured, the diminution from the last reading will represent the amount of oxygen originally present in the gas. It is essential that the coke bullet, after saturation with the alkaline solution of pyrogallic acid, should not come into contact with the air before its introduction into the gas.

III. Estimation of the Luminiferous Constituents.

Various methods have been employed for the estimation of the so-called olefiant gas (luminiferous constituents) contained in coal-gas. The one which has been most generally employed, depends upon the property which is possessed by olefiant gas, and most hydrocarbons, of combining with chlorine, and condensing to an oily liquid: hydrogen and light carburetted hydrogen are both acted upon in a similar manner when a ray even of diffused light is allowed to have access to the mixture; but the condensation of the olefiant gas and hydrocarbons takes place in perfect darkness, and advantage is therefore taken of this circumstance to observe the amount of condensation which takes place when the mixture is excluded from light. The volume, which disappears during this action of the chlorine, is regarded as indicating the quantity of olefiant gas present in the mixture. There are many sources of error inseparably connected with this method of operating, which render the results unworthy of the slightest confidence; the same remark applies also to the employment of bromine in the place of chlorine; in addition to the circumstance that these determinations must be made over water, which allows a constant diffusion of atmospheric air into the gas, and vice versa, there is also formed in each case a volatile liquid, the tension of the vapor of which increases the volume of the residual gas; and this increase admits of neither calculation nor determination. The only material by which the estimation of the luminiferous constituents can be accurately effected is anhydrous sulphuric acid, which immediately condenses the luminiferous constituents of coal-gas, but has no action upon the other ingredients, even when exposed to sunlight. The estimation is conducted as follows: A coke bullet prepared as described above, and attached to a platinum wire, being rendered thoroughly dry by slightly heating it, for a few minutes, is quickly immersed in a saturated solution of anhydrous sulphuric acid, in Nordhansen sulphure acid, and allowed to remain in the liquid for one minute; it is then withdrawn, leaving as little superfluous acid adhering to it as possible, quickly plunged beneath the quicksilver in the trough, and introduced into the same portion of dry gas, from which the carbonic acid and oxygen have been withdrawn by experiments I. and II.; here it is allowed to remain for about two hours, in order to ensure the complete absorption of every trace of hydrocarbons. The residual volume of gas cannot, however, yet be determined, owing to the presence of some sulphurous acid derived from the decomposition of a portion of the sulphuric acid: this is absorbed in a few minutes by the introduction of a moist bulb of peroxide of manganese, which is readily made by converting powdered peroxide of manganese into a stiff paste with water, rolling it into the shape of a small bullet, and then inserting a bent platinum wire, in such
a manner as to prevent its being readily drawn out; the bell should then be put in a warm place, and allowed slowly to dry, it will then become hard, and possess considerable cohesion, even after being moistened with a drop of water, previous to its introduction into the gas. After half an hour, the bullet of peroxide of manganese may be withdrawn, and replaced by one of caustic potash, to remove the watery vapor introduced with the previous one; at the end of another half hour, this bullet may be removed, and the volume of the gas at once read off. The difference between this and the previous reading, gives the volume of the luminiferous constituents contained in the gas. This method is very accurate; in two analyses of the same gas, the percentage of luminiferous constituents seldom varies more than 0.1 or 0.2 per cent.

IV. Estimation of the Non-Luminiferous Constituents.

These are light carburetted hydrogen, hydrogen, carbonic oxide, and nitrogen. The percentages of these gases are ascertained in a graduated eudiometer, about 2 feet in length, and \( \frac{1}{5} \) of an inch internal diameter; the thickness of the glass being not more than \( \frac{3}{4} \) of an inch. This eudiometer is furnished at its closed end with two platinum wires, fused into the glass, for the transmission of the electric spark. A drop of water, about the size of a pin's head, is introduced into the upper part of the eudiometer before it is filled with mercury and inverted into the mercerual trough: this small quantity of water serves to saturate with aqueous vapor the gases subsequently introduced. About a cubic inch of the residual gas from the last determination is passed into the eudiometer, and its volume accurately read off: about 4 cubic inches of pure oxygen are now introduced, and the volume (moist) again determined. The oxygen is best prepared at the moment when it is wanted, by heating over a spirit or gas flame a little chlorate of potash, in a very small glass retort, allowing of course sufficient time for every trace of atmospheric air to be expelled from the retort before passing the gas into the eudiometer. The open end of the eudiometer must now be pressed firmly upon the thick piece of India-rubber placed at the bottom of the trough, and an electric spark passed through the mixture; if the above proportions have been observed the explosion will be but slight, which is essential if nitrogen be present in the gas, as this element will otherwise be partially converted into nitric acid, and thus vitiate the results.

By using a large excess of oxygen, all danger of the bursting of the eudiometer by the force of the explosion is also avoided. The volume after explosion being again determined, a bullet of caustic potash is introduced into the gas, and allowed to remain so long as any diminution of volume takes place; this bullet absorbs the carbonic acid that has been produced by the combustion of the light carburetted hydrogen and carbonic oxide, and also renders the residual gas perfectly dry; the volume read off after this absorption, when deducted from the previous reading, gives the volume of carbonic acid generated by the combustion of the gas.

The residual gas now contains only nitrogen and the excess of oxygen employed. The former is determined by first ascertaining the amount of oxygen present, and then deducting that number from the volume of both gases; for this purpose a quantity of dry hydrogen, at least three times as great as the residual gas, is introduced, and the volume of the mixture determined; the explosion is then made as before, and the volume (moist) again recorded: one-third of the contraction caused by this explosion represents the volume of oxygen, and this deducted from the volume of residual gas, after absorption of carbonic acid, gives the amount of nitrogen.

The behavior of the other three non-luminous gases on explosion with oxygen enables us readily to find their respective amounts by three simple equations, founded upon the quantity of oxygen consumed, and the amount of carbonic acid generated by the three gases in question. Hydrogen consumes half its own volume of oxygen, and generates no carbonic acid; light carburetted hydrogen consumes twice its volume of oxygen, and generates its own volume of carbonic acid; whilst carbonic oxide consumes half its volume of oxygen, and generates its own volume of carbonic acid. If, therefore, we represent the volume of the mixed gases by \( A \), the amount of oxygen consumed by \( B \), and the quantity of carbonic acid generated by \( C \), and further, the volumes of hydrogen, light carburetted hydrogen, and carbonic oxide respectively by \( x, y, \) and \( z \), we have the following equations:

\[
\begin{align*}
x + y + z &= A \\
4x + 2y + 1.5z &= B \\
y + z &= C
\end{align*}
\]

From which the following values for \( x, y, \) and \( z \) are derived:

\[
\begin{align*}
x &= A - C \\
y &= \frac{2B - A}{3} \\
z &= C - \frac{2B - A}{3}
\end{align*}
\]
V. Estimation of the Value of the Luminiferous Constituents.

We have now given methods for ascertaining the respective quantities of all the ingredients contained in any specimen of coal-gas, but the results of the above analytical operations afford us no clue to its illuminating power. They give us, it is true, the amount of illuminating hydrocarbons contained in a given volume of the gas, but it will be evident, from what has already been said respecting the luminiferous powers of these hydrocarbons, that the greater the amount of carbon contained in a given volume, the greater will be the quantity of light produced on their combustion; and therefore, as the number of volumes of carbon vapor contained in one volume of the mixed constituents, condensable by anhydrous sulphuric acid, has been found to vary from 2.54 to 4.06 volumes, it is clear that this amount of carbon vapor must be accurately determined for each specimen of gas, if we wish to ascertain the value of that gas as an illuminating agent. Fortunately this is easily effected; for if we ascertain the amount of carbonic acid generated by 100 volumes of the gas in its original condition, knowing from the preceding analytical processes the percentage of illuminating hydrocarbons, and also the amount of carbonic acid generated by the non-luminiferous gases, we have all the data for calculating the illuminating value of the gas. For this purpose a known volume of the original gas (about one cubic inch) is introduced into the explosion cuidimeter, and mixed with about five times its volume of oxygen, the electric spark is passed, and the volume of carbonic acid generated by the explosion ascertained as above directed. If we now designate the percentage of hydrocarbons absorbed by anhydrous sulphuric acid by $A$, the volume of carbonic acid generated by 100 volumes of the original gas by $B$, the carbonic acid formed by the combustion of the non-luminous constituents remaining after the absorption of hydrocarbons from the above quantity of original gas by $C$, and the volume of carbonic acid generated by the combustion of the luminous compounds (hydrocarbons) by $x$, we have the following equation:

$$ x = B - C $$

and therefore the amount of carbonic acid generated by one volume of the hydrocarbons is represented by

$$ \frac{B - C}{A} $$

But as one volume of carbon vapor generates one volume of carbonic acid, this formula also expresses the quantity of carbon vapor in one volume of the illuminating constituents. For the purpose of comparison, however, it is more convenient to represent the value of these hydrocarbons in their equivalent volume of olefiant gas, one volume of which contains two volumes of carbon vapor; for this purpose the last expression need only be changed to

$$ \frac{B - C}{2A} $$

Thus, if a sample of gas contain 10 per cent. of hydrocarbons, of which one volume contains three volumes of carbon vapor, the quantity of olefiant gas to which this 10 per cent. is equivalent, will be 15.

By the application of this method we obtain an exact chemical standard of comparison for the illuminating value of all descriptions of gas; and by a comparison of the arbitrary numbers thus obtained, with the practical results yielded by the same gases when tested by the photometer, much valuable and useful information is gained.

Analysis of Coal-Gas with Frankland and Ward's Apparatus.—Introduce a few cubic inches of the gas into the tube $r$, fig. 173, and transfer it for measurement into $r$, by opening the cocks $h$ and placing the tube $r$ in communication with the exit pipe $h$, the transfer being assisted, if needful, by elevating the trough $c$. When the gas, followed by a few drops of mercury, has passed completely into $r$, the cock $f$ is shut, and $f$ turned, so as to connect $r$ and $h$ with $h$. Mercury is allowed to flow out until a vacuum of two or three inches in length is formed in $h$, and the metal in $r$ is just below one of the divisions; the cock $f$ is then reversed, and mercury very gradually admitted from $a$, until the highest point in $r$ exactly corresponds with one of the divisions upon that tube; we will assume it to be the sixth division. This adjustment of mercury and the subsequent readings can be very accurately made by means of a small horizontal telescope placed at a distance of about six feet from the cylinder, and sliding upon a vertical rod. The height of the mercury in $h$ must now be accurately determined, and if from the number thus read off, the height of the sixth division above the zero of the scale on $h$ be deducted, the remainder will express the true volume of the gas. As the temperature is maintained constant during the entire analysis, no correction on that score has to be made; the atmospheric pressure being altogether excluded from exerting any influence upon the volumes or pressures, no barometrical observations are requisite; and as the tension of aqueous vapor in $r$ is exactly balanced by that in $h$, the instrument is in this respect also self-correcting. Two or three drops of a strong
solution of caustic potash are now introduced into \( r \) by means of a bent pipette, and mercury being allowed to flow into \( s \) and \( t \) by opening the cock \( b \), the gas returns into \( t \) through \( l' \), and there coming into contact with an extensive surface of caustic potash solution, any carbonic acid that may be present will be absorbed in two or three minutes, and the gas being passed back again into \( n \) for remeasurement, taking care to shut \( l \) before the caustic potash solution reaches \( l' \), the observed diminution in volume gives the amount of carbonic acid present.

The amount of oxygen is determined in like manner by passing up into \( r \) a few drops of a saturated solution of pyrogallic acid, which forms with the potash already present pyrogallate of potash. The gas being then brought back into \( r \), oxygen, if present, will be absorbed in a few minutes. Its amount is of course ascertained by remeasuring the gas in \( r \).

The next step in the operation consists in estimating the amount of olefiant gas and illuminating hydrocarbons. For this purpose, whilst the gas, thus deprived of oxygen and carbonic acid, is contained in \( r \), the tube \( t \) must be removed, thoroughly cleansed and dried, and being filled with mercuric, must be again attached to \( l \). The gas must now be transferred from \( r \) to \( t \), and a coke bullet, prepared as above described, being passed up into \( t \), must be allowed to remain in the gas for one hour. After its removal, a few drops of a strong solution of dichromate of potash must be admitted into \( r \) in order to absorb the sulphurous acid and vapors of anhydrous sulphuric acid resulting from the previous operation. The gas is now ready for measurement; it is therefore passed into \( r \), and its volume determined; the diminution which has occurred since the last reading represents the volume of olefiant gas and illuminating hydrocarbons that were present in the gas.

It now only remains to determine the respective amounts of light carbonated hydrogen, carbamate oxide, hydrogen, and nitrogen present in the residual gas. This is effected as follows:—As much of the residual gas as will occupy about \( \frac{1}{2} \) inch of its length at atmospheric pressure is retained in \( r \), and its volume accurately determined; the remainder is passed into \( s \), and the latter tube removed, cleansed, filled with mercury, and reattached. A quantity of oxygen equal to about three-and-a-half times that of the combustible gas is now added to the latter, and the volume again determined; then the mixture having been expanded to about the sixth division, an electric spark is passed through it by means of the wires at \( m \). The contraction resulting from the explosion having been noted, two or three drops of caustic potash solution are passed into \( t \), and the gas is then transferred into the same tube. In two minutes the carbamic acid generated by the explosion is perfectly absorbed, and its volume is determined by a fresh measurement of the residual gas. The latter must now be exploded with three times its volume of hydrogen, and the contraction on explosion noted. These operations furnish all the data necessary for ascertaining the relative amounts of light carbonated hydrogen, carbamic oxide, hydrogen, and nitrogen, according to the mode of calculation given above.

Finally, the value of the luminiferous constituents is obtained as before, by exploding about a cubic inch of the original specimen of gas with from four to five times its volume of oxygen, and noting the amount of carbamic acid produced.

### I. Apparatus used in the Generation of Coal-Gas.

**Retorts.—**The use of this portion of the apparatus is to expose the coal to a high temperature, to exclude atmospheric air, and to deliver the gaseous and vaporous products of distillation into the refrigeratory portion of the apparatus. The materials composing the retorts should therefore possess the following properties:—1st, high conducting power for heat; 2d, rigidity and indestructibility at a high temperature; and 3d, impermeability to gaseous matter. The materials hitherto used in the construction of retorts are cast-iron, wrought-iron, and earthenware; but none of these materials possess the above qualifications in the high degree that could be wished. Thus cast-iron, though a good conductor of heat, is not perfectly rigid and indestructible. At high temperatures it becomes slightly viscous, and at the same time undergoes rapid oxidation. Wrought-iron is a still better conductor of heat, but its qualities of indestructibility and rigidity are even lower than those of cast-iron; whilst earthenware, though rigid and indestructible by oxidation, is a very bad conductor of heat, and is moreover very liable to crack from changes of temperature. Very various forms of retort have been employed at different times in order to secure, as far as possible, the conditions just enumerated.

**Cast-iron Retorts.—**The chief forms of the cast-iron retorts are: First, the cylindrical, fig. 174, used in the Manchester Gas Works, 12 inches diameter, and 6 to 9 feet long; Second, the elliptical, 18 inches by 12 inches, by 6 to 9 feet, fig. 175; Third, the ear
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shape, *fig. 176*, now little used, 2 feet by 9 inches, and of the same length as before; Fourth, the D-shaped retort, *fig. 177*, 20 inches wide and 14 inches high. This form of retort is at present far more extensively used than any of the others.

*Fig. 178 shows a bed of 5 D-shaped iron retorts. The length is 7½ feet, and the transverse area, from one foot to a foot and a half square. The arrows show the direction of the flame and draught.*

The charge of coals is most conveniently introduced in a tray of sheet-iron, made somewhat like a grocer's scoop, adapted to the size of the retort, which is pushed home to its further end, inverted so as to turn out the contents, and then immediately withdrawn.

All these retorts are set horizontally in the furnace, and they have a flange cast upon their open end, to which a mouthpiece $\&c.$, *fig. 179*, can be securely bolted. The mouth-piece is provided with a socket $b$, for the reception of the *standpipe*, and also with an arrangement by which a lid $c$ can be screwed gas-tight upon the front of the mouth-piece, as soon as the charge of coal has been introduced. By applying a luting of lime mortar to that part of the lid which comes into contact with the mouth-piece, a perfectly tight joint is obtained.

Sometimes iron retorts are made of double the above length, passing completely through the furnace, and being furnished with a lid and standpipe at each end. Such is the construction of Mr. Groll's and of Lowe's reciprocating retorts. These retorts are charged from each end alternately, and there is an arrangement of valves by means of which the gas evolved from the coal recently introduced is made to pass over the incandescent coke of the previous charge, at the opposite end of the retort. It is highly probable that some advantage is derived from this arrangement during the very early stage of the distillation of the fresh coal; but on the whole, for reasons stated above, the principle is undoubtedly bad, for although it enables the manufacturer to produce a larger volume of gas, the quality is so much inferior as to reduce the total illuminating effect obtainable from a given weight of coal.

Wrought-Iron Retorts.—Mr. King, the eminent engineer of the Liverpool Gas Works, has for many years successfully used retorts of wrought-iron. They are made of thick boiler plates, riveted together, and are of the D shape, 5½ feet wide, 6 feet long, and 18 inches high at the crown of the arch. About 1 ton of coal can be worked off in these retorts in 24 hours. Occasionally the bottoms are of cast-iron, which materially prevents the great amount of warping to which wrought-iron is subject when exposed to high temperatures.

Earthenware, or Clay Retorts.—These are usually of the D shape, although they are occasionally made circular or elliptical. Their dimensions are about the same as those of the cast-iron retorts commonly used, but their walls are necessarily thicker, varying from 2½ to 4 inches in thickness; this, added to the circumstance that clay is a very bad conductor of heat, undoubtedly causes the expenditure of a larger amount of fuel in heating these retorts; nevertheless, this disadvantage is, perhaps, less than might be supposed, since iron retorts soon become coated outside with a thick layer of oxide of iron, which also greatly hinders the free communication of heat to the iron beneath. Moreover, the lower price and much greater durability of clay retorts, are causing their almost universal adoption in gas works, especially since the removal of pressure by exhaustors greatly reduces the amount of leakage to which clay retorts are liable.

The following is an extract relating to clay retorts, from the "Reports of Juries" of the great Exhibition of 1851:

"The use of fire-clay is not of very ancient date, and has greatly increased within the last few years. It is found in England almost exclusively in the coal measures, and
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from different districts the quality is found to differ considerably. The so-called "Stourbridge clay" is the best known, and will be alluded to presently; but other kinds are almost, if not quite, as well adapted for the higher purposes of manufacture, being equally free from alkaline earths and iron, the presence of which renders the clay fusible when the heat is intense. The proportions of silica and alumina in these clays vary considerably, the former amounting sometimes to little more than 50 per cent., while in others it reaches beyond 70, the miscellaneous ingredients ranging from less than $\frac{1}{2}$ to upwards of 7 per cent.

The works of Messrs. Cowen & Co. are among the most extensive in England, and they obtain their raw material from no less than nine different seams, admitting of great and useful mixture of clay for various purposes.

"After being removed from the mine, the clay is tempered by exposure to the weather, in some cases for years, and is then prepared with extreme care. The objects chiefly made are fire-bricks and gas retorts—the latter being now much used, and preferred to iron for durability.

"These retorts were first made by the present exhibitors in ten pieces, (this being twenty years ago,) and since then the number of pieces has been reduced successively to four, three, and two pieces, till in 1844 they were enabled to patent a process for making them in one piece, and at the present time they are thus manufactured of dimensions as much as 10 feet long by 3 feet wide in the inside, which is, however, more than double the size of the largest exhibited by them.
"Gas retorts of very fair quality are shown by Mr. Ramsay of Newcastle, who has also succeeded extremely well in the manufacture of fire-bricks. The retorts show a little more iron than is desirable, but the exhibitor has been considered worthy of honorable mention. Retorts of less creditable appearance are exhibited by Messrs. Hickman & Co. of Stourbridge, and Mr. A. Potter of Newcastle. The surface of both these retorts is cracked and undulating. When we consider the high and long-continued temperature to which these objects are exposed, the absolute necessity of attending to every detail in mixing the clay and moulding the retort will be at once recognized, and the apparently slight defects of some of those sent for exhibition require to be noticed as of real importance.

"Next to England, the finest specimens of fire-clay goods on a large scale are from Belgium: the gas retort sent from France is not remarkable for excellence."

Fig. 180 is an elevation of Mr. Wright's plan for a range of long clay retorts.
Fig. 181 shows the plans and sections of the setting for these retorts.

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Retorts, or rather ovens, of fire-brick, the invention of Mr. Spinney, have been long used successfully at Exeter, Cheltenham, and other places. They appear to be very durable, and to require little outlay for repairs, but a very large expenditure of fuel is required for heating them. They are of the D shape, 7 feet long, 3 feet 2 inches wide, and 14 inches high at the crown of the arch. Each retort receives a charge of 5 or 6 cwt. of Newcastle or Wesh coal every 12 hours, and produces gas at the rate of 9,000 cubic feet per ton of Welsh, and 10,000 to 12,000 per ton of Newcastle coal.

Clegg's Revolving Web Retort.—This retort, the invention of Mr. Clegg, sen., makes the nearest approach to a truly philosophical apparatus for the generation of gas; in it the coal is exposed to a sudden and uniform heat, in a thin stratum, by which means the gases are liberated at once, and under the conditions most favorable for the production of a maximum amount of illuminating constituents. Very little tar is produced from this retort.

Fig. 182 represents a section of this retort, which is of the D shape, with a very low and flat arch. It is made of wrought-iron boiler plates riveted together. \( x \) is a hopper for holding the coal to be carbonized; \( f \) is a discharging disc; \( a \) is the retort; \( h \) is a web on to which the coal is discharged by the disc \( f \); \( r \) are revolving drums carrying the wrought-iron web \( y \); \( l l \) are the flues from a lateral furnace by which the retort is heated; \( m \) is the exit pipe for the coke, its lower extremity is either closed by an air-tight door, or is made to dip into water.

![Diagram of Clegg's Revolving Web Retort](image)

All the coal must be reduced to fragments about the size of coffee berries, and a 24 hours' charge must be placed at once in the hopper, and secured by a luted cover. The discharging disc has 6 spurs, and is made to revolve uniformly with the drum below it at the rate of 4 revolutions per hour. The diameter of the hexagonal drums is so regulated, that the coal, which falls upon the web from the discharging disc, will at one revolution have passed the entire length of the retort. The passage through the retort occupies 15 minutes, which is quite sufficient to expel the whole of the gas from the coal. In each revolution of the disc and drum, 745 cubic inches of coal (or 21 lbs.) are distributed over a heated surface of 2,016 square inches. 18 cwt. of coal is carbonized in one of these retorts in 24 hours, and the production of gas is equal to 12,000 cubic feet per ton of Newcastle coal. The quality of the gas is also considerably superior to that obtained from the same coal in the ordinary retorts.

Although the first cost of these retorts and accompanying machinery is considerably greater than that of the retorts in ordinary use, yet the destructible parts can be replaced at about the same cost as that required to replace the latter. The coke produced is greater in quantity, but inferior in quality, owing to its more minute state of division. The minor advantages attendant upon this form are, that it occupies less space, requires much less manual labor, and enables the retort-house to be kept perfectly clean, wholesome, and free from suffocating vapor. If the principle of this plan could be combined with less complication of details, it would no doubt come into extensive use.
II. The Refrigeratory Apparatus.

From the moment that the gas leaves the retorts, it is subjected to cooling influences which gradually reduce its temperature, until on leaving the so-called condenser its temperature ought to be only a few degrees higher than that of the atmosphere, except in winter, when it is advisable to maintain a heat, relatively to the external air, greater than in summer. The gas leaves the retort by the standpipes A A A A, fig. 183, which are of cast-iron, 5 inches in diameter at their lower extremity, and slightly tapering upwards. Some of the least volatile products of decomposition condense in these pipes, but their proximity to the furnaces, and the constant rush of heated gas and vapor through them, prevent more than a very slight amount of refrigeration. They conduct to the hydraulic main, which is shown at B, fig. 183. It consists of a cylinder running the entire length of the retort house, and fixed at a sufficient height above the mouths of the retorts to protect it from the flame issuing from the latter during the times of charging and drawing. The diameter varies from 12' to 18 inches, and the recurved extremities of the standpipes (the dip-pipes) c c c c, pass through it by gas-tight joints, and dip, to the extent of 3 or 4 inches, into the condensed liquids contained in the hydraulic main. The use of this portion of the apparatus is to cut off the communication in the reverse direction between the gas beyond the standpipes and the retorts, so as to prevent the former rushing back down the standpipe during the time that the lid of the retort is removed. Being maintained half full of tar it effectually seals the lower ends of the dip-pipes, and prevents any
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return of gas towards the retorts. The condensed products, consisting chiefly of tar, make their exit from the hydraulic main by the pipe a, which leads them to the tar well. From the hydraulic main the gas passes to the condenser, the office of which, as its name implies, is to effect the condensation of all those vapors which could not be retained by the gas at the ordinary atmospheric temperature. The condenser has received a variety of forms, but the one which appears to unite in the highest degree simplicity and efficiency, is the invention of Mr. Wright, of the Western and Great Central Gas Companies. Its construction is shown in fig. 184. A A A A are 5 double concentric cast-iron cylinders, through which the gas is made to circulate in succession by means of the tie-pipes b b b b b, whilst the inner cylinders being open above and below, a current of air, set in motion by their heated walls, rushes through them, thus securing both an internal and external refrigeration action. It will be also seen by a reference to the figure, that the heated gas enters these cylinders at the top, taking an opposite direction to that pursued by the external and internal currents of air, and thus securing the most perfect refrigeration, by bringing the gas constantly in proximity to air of increasing coldness. Each cylinder is furnished at bottom with a tar receptacle c, for the collection of the condensed products, which are carried to the tar well by a pipe not shown in the figure. The details of construction are sufficiently seen from the drawing, and require no further description.

In some country works the condenser is used.

The extent of surface which the gas requires for its refrigeration before it is admitted into the washing-line apparatus, depends upon the temperature of the milk of lime, and the quantity of gas generated in a certain time. It may be assumed as a determination sufficiently exact, that 10 square feet of surface of the condenser can cool a cubic foot of gas per minute to the temperature of the cooling water. For example, suppose a furnace or arch with 5 retorts of 150 pounds of coal each, to produce in 5 hours 3,000 cubic feet of gas, or 10 cubic feet per minute, there would be required, for the cooling surface of the condenser, 100 square feet = 10 × 10. Suppose 100,000 cubic feet of gas to be produced in 24 hours, for which 8 or 9 such arches must be employed, the condensing surface must contain from 800 to 900 square feet.

After the action of the condenser, the gas still retains, chiefly in mechanical suspension, a certain quantity of tarry matter, besides a slight percentage of ammonia. To free it from these, it is passed through a scrubber d (fig. 184), which consists of a tall cylinder filled with bricks, paving stones, or coke, and having an arrangement by which a stream of water can be applied at top and removed at bottom. The chief use of the water is to remove ammonia from the gas, but as it also dissolves some of the luminiferous hydrocarbons, its use is objected to by Mr. Wright, and dry scrubbers are now used at the Western Gas Works. It is also considered by the same gentleman, that the detention of a certain percentage of ammonia by the gas, is rather an advantage than otherwise, as it serves in part to neutralize the sulphurous acid which is inevitably produced by the combustion even of the best gas. It must, however, be borne in mind, that the presence of ammonia in gas gives rise to the formation of nitric acid during its combustion.

The Exhauster.—The passage of the gas through the liquid of the hydraulic main, and the other portions of apparatus between the retorts and gas-holder, causes a very considerable amount of pressure to be thrown back upon the retorts,—an effect which is productive of mischief in two ways; in the first place, if there be any fissure or flaw in the retorts, or leakage in the joints, the escape and consequent loss of gas is greatly augmented; and in the second place, it has been ascertained by Mr. Grafton, of Cambridge, that pressure in the retorts causes the decomposition of the illuminating hydrocarbons with greatly increased rapidity. It is, therefore, very desirable to remove nearly the whole of this pressure by mechanical means, and this is now done in all well-arranged works, by the use of an apparatus termed an exhauster. Several forms of exhausters are in use, but it will be necessary only to describe that of Mr. J. T. Beale, which has been found by experience to be very effective and economical. It is shown in section in fig. 185. The axle a is reduced at each end, and passes into two cylindrical boxes bored to a larger diameter than the axle at those parts; and in the annular space between the axle and the box anti-friction rollers are introduced, their diameter being equal to the width of the annular space; the box at one end is fitted with a stuffing-box, through which the axle passes for the application of the driving power. Upon motion being given to the axle, the sliding pistons b b are carried with it. These sliding pistons are furnished at their ends with cylindrical pins which project and fit into cylindrical holes bored in the guide blocks c c, which fit into annular recesses b in the end plates, and keep the slides in contact with the cylinder. The slides are fitted with metallic packing e, to allow of wear. The axle continuing to revolve, as one slide reaches the outlet and ceases to exhaust, the other comes into action, and the exhauster is unceasing. Thus the pressure upon the retorts (which is indicated by a gauge) is reduced to about half an inch of water.

In order to judge of the degree of purity of the gas after its transmission through the lime machine, a slender siphon tube provided with a stopcock may have the one end in
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sorbed in its cover, and the other dipped into a vessel containing a solution of acetate of lead. Whenever the solution has been rendered turbid by the precipitation of black sul-

phuric acid, it should be renewed. The saturated and fetid milk of lime is evaporated in oblong cast-iron troughs placed in the ash-pit of the furnaces, and the dried lime is partly employed for lining the apparatus, and partly disposed of for a mortar or manure.

III. APPARATUS USED IN THE PURIFICATION OF COAL-GAS.

Figs. 186 and 187 represent the form of a dry purifier, combined with a washer or scrubber, lately patented by Mr. Lees of Manchester. Fig. 186 is an elevation, partly in section of this apparatus, and Fig. 187 is another elevation, also partly in section, of the same. a is a hopper, into which the dry lime is fed; b is a damper, or sliding door, by which the supply of lime can be regulated; c is a sheet metal tube, containing the worm or screw d, the axis of which is supported at one end by the stuffing-box e, and at the other end by the bearing f. A slow revolving motion is given to the worm d from the driving shaft g, by means of the bevel wheels h, upright shaft i, worm j, and worm wheel k, fixed on the axis of the worm.

The lime in the hopper a, is kept in motion by the screw n, which is turned slowly round by the worm g, the worm wheel o and bevel wheels p, one of which is fixed on the screw n. The tube e is open at e', to admit the dry lime from the hopper a, and the worm or screw d is furnished with cross pieces e' to agitate the lime, which is gradually moved from the hopper to the other end of the tube e, by the revolving of the worm. Below the tube e is another tube l; y is a siphon, by which the washing fluid is supplied and conducted to the chamber r, which then flows down the tube l to the chamber r, keeping the level indicated by j. b, z are two paddles, fixed upon the circular perforated plates, which are set to an angle, and secured to the shaft w', and are revolved speedily by the strap and pulleys x. These agitators serve to increase the action of the washing fluid contained in the tube l, by which the gas is washed previous to passing through the dry lime purifier.

The mode of operation is as follows:—The gas to be purified is admitted through the pipe g, to the chamber r, from whence it passes along the tube l, as shown by the arrows, to the chamber r; it then rises into the chamber t and enters the tube e, along which it passes in the direction shown by the arrows whence it may be conveyed, through the pipe v, to the gasometer.
It will be apparent, as the gas passes along the tube $l$, containing the agitators $m$, which are caused to revolve speedily by the motion given by the straps and speed pulleys $x$, that the washing fluid, which is passing regularly through the siphon $y$, and running into the chamber $z$, and along the tube $l$, into the chamber $r$, keeping the level as shown by $j$, is caused to be revolved into a centrifugal motion round the tube $l$, by the two paddles $a$, placed upon the circular perforated plates, secured upon the shaft $n$, which are set to an angle, thereby causing a counter-motion from left to right of the tube $l$, and causing the washing fluid to be wrought into a complete spray amongst the gas, whereby the heavier parts of the impurities are carried away more effectually than by any other washers in use.

The gas then enters the chamber $t$ through the tube $c$, passes along the coils or threads of the worm or screw $d$, and as the cross pieces $e$ are set to an angle, as shown in fig. 187, the lime is raised from the lower to the upper part of the tube $e$, and then drops down to the gas that is making its way towards the openings $c$; consequently, the lime and the gas become most intimately mixed, whereby the lime is made to absorb a much greater proportion of the impurities contained in the gas than is effected by the dry lime purifiers usually employed, in which the lime is supported on stationary trays. The lime dropping into the tube $c$ from the hopper $a$, is worked gradually towards the chamber $t$, into which it drops. The speed of the screw or worm $d$, the number of threads upon it, the length and diameter thereof, must be made to suit the quantity of gas to be purified per hour. The lime which drops into the chamber $t$, may be removed therefrom through the manhole $e$. Mr. Lees states that a considerable saving is effected in the lime, owing to each particle or atom being kept in motion, and falling repeatedly through the gas in its passage from one end of the tube to the other, and that there is also a great saving in labor.

Another form of wet purifier, which might also be advantageously used as a scrubber, or as a naphthalizer, has recently been invented by M. Colladon of Geneva, and is now in

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use in the gas manufactory of that city. This apparatus, as shown in vertical section in fig. 188, consists of a section of a very obtuse cone \( \Lambda' \), the angle of inclination of which is 164°. Its upper and smaller end is joined to a metal cylinder \( \Lambda \) placed on the same axis as \( \Lambda' \), and about its own diameter in height. At top it is closed by a cast-iron plate \( \kappa \), through which the axle \( c \) passes: the latter communicates a rotary motion to the cylinder and cone \( \Lambda \) and \( \Lambda' \). It is inclined 8° from the perpendicular, and rests upon the steel point of the centre pin \( b' \), whilst at top it carries a pulley by which a circular motion is communicated to it. \( a a \) are a series of metal discs which stand vertically to the inner surface of the cone \( \Lambda' \), with spaces of about one inch between them. The discs are arranged concentrically, and have spaces corresponding to the quantity of gas which has to pass through them. They are from 5 to 7 inches long. As the axle \( c \) and cylinder \( \Lambda \) are not vertical, but somewhat inclined, one side of the cone \( \Lambda' \) will, during the revolution, be in a nearly horizontal position, whilst the opposite side will be immersed in the liquid to the extent of about 16°. The whole of this mechanism is enclosed in a sheet-iron lid \( b \). The centre pin \( b \) is attached by a cross-bar to the lower edge of \( b \), whilst the axle \( c \) is supported by \( d \), which is also attached to \( b \). \( d' d' \) is a water joint permitting of the free motion of \( c \). The lid \( b \) thus contains the whole of the washing apparatus, and it is held in its proper position in the trough \( c \) by lateral attachments. \( \theta \) is the inlet pipe opening into the cylinder \( \Lambda \), from which it has to make its way through the discs \( a a \) to the outlet \( e \). This apparatus gives no sensible pressure, and requires a very small motive power.

![Diagram](image-url)

Fig. 189 represents an arrangement of four of the dry purifiers, worked by a central valve, as used at the present time in most large gas-works; it is the invention of Mr. Malam, and is described in Mr. Peckston's treatise. \( a, b, c, d \), are the four purifiers connected with the central valve \( e \) in such a way as to permit of three of them being at work whilst the
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fourth is emptied and recharged. The outer case of the central valve $e$, is a cylinder of cast- or wrought-iron, 5 to 6 feet in diameter and 3 to 4 feet deep. Its floor receives the open ends of 10 pipes conducting the gas from the condenser or exhauster to the different purifiers, and then to the gas-holders; the ends of these pipes project upwards to the height of 14 inches, and the vessel is filled with water to the height of 12 inches, thus leaving the orifice of the pipes 2 inches above the water level. This cylinder has a cover which consists of a smaller cylinder, open below and closed above, fitting into $e$, so as to form a water lute. Its interior is divided into 5 chambers, as shown in fig. 190, and when the cover is so far lowered into $e$ as to immerse the edges of these chambers into the water, they each connect together a pair of pipes, as shown in fig. 189, at $e$, which exhibits a horizontal section through these chambers. The chambered cover being placed in the position shown in fig. 189, the gas takes the following course: it enters the chamber $a'$ by the pipe $a$, passes through the pipe marked 1 into the bottom of the purifier $c$, and after traversing the layers of purifying material in $c$, it returns to chamber $e$ of the central valve by the pipe 2; thence by pipe 3, it enters the purifier $n$, and returns to chamber $d$ of the valve by pipe No. 4. From this chamber it can only make its exit by pipe No. 5, which conducts it into $a$, whence it returns to chamber $b$ by pipe No. 6, and from this chamber it finally passes to the gas-holder through the exit pipe $b$. Thus the purifier $a$ is left out of the circuit for the purpose of recharging or revivification; but when the material in $c$ has become exhausted, it can be replaced, in the circuit by $a$, by slightly raising the cover of $e$, and turning it round so as to bring the chamber $a'$ over pipe 3, and again depressing it to its former position; by this arrangement $n$, $u$ and $a$ become the working purifiers, whilst $c$ will be thrown out of the circuit. Thus, by the action of the central valve $e$, each of the four purifiers can in turn be excluded from the circuit, and recharged or revivified.

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The Governor.—Although the gas-holder is, to a certain extent, a regulator of pressure, yet it is difficult, by its action alone, to maintain a pressure so steady and uniform as that required for the supply of gas consumers. It would be difficult, if not impossible, to alter
the pressure upon the mains frequently during a single night, as is now usually done in towns with a large number of street lamps, without the intervention of an apparatus termed a *governor*. The governor, which occupies a position between the gas-holder and supply mains, is a miniature gas-holder $s$, (see figs. 191, 192, and 193, which represent Ma 192

Wright's improved governor,) the interior of which, however, is nearly filled by the concentric inlet and outlet pipes $b$ and $c$. Immediately over the mouth of the inlet pipe, and depending from the roof of the inner cylinder, is a parabolic piston $p$, which hangs within the contracted mouth of the inlet pipe $c$. The interior cylinder is counterpoised by the lever and weights $e$. Now, when the pressure of gas in this small holder increases,—that
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is, when the flow of gas through the inlet pipe exceeds that escaping from the outlet,—the inner cylinder rises; but in doing so, it carries with it the parabolic piston, and thus contracts the orifice of the inlet, and consequently diminishes the ingress of gas. In this way, by adjusting the weights attached to the lever of the governor, and by always maintaining a pressure in the gas-holder greater than is required in the mains, the gas can be delivered from the governor at any required pressure. In hilly towns, such as Bristol, Bath, Edinburgh, &c., it is necessary to employ governors at different stages of elevation, in order to produce a tolerably uniform pressure in the different districts. The necessity for this will be obvious, when it is stated, that a difference of level of 30 feet affects the pressure of the gas in the mains to the extent of \( \frac{9}{16} \) of an inch of water.

ECONOMICAL AND SANITARY RELATIONS OF GAS.

In a lecture delivered at the Royal Institution in 1853, Dr. Frankland estimates the comparative cost of an amount of light from various sources equal to that yielded by 20 sperm candles, each burning 120 grains per hour for 10 hours.

| Wax | S. d. | London gases: City, Great Central, |
| Spermaceti | 7 2½ | Imperial, and Chartered | 0 4¼ |
| Tallow | 6 8 | Western | 0 2¼ |
| Sperm oil (Carcel’s lamp) | 2 8 | Manchester gas | 0 3 |

The following table exhibits the amount of carbonic acid and heat produced per hour from the above sources of light, the heat generated by tallow being assumed to be 100 for the purposes of comparison.

<table>
<thead>
<tr>
<th>Carbonic Acid</th>
<th>Heat</th>
<th>Cubic feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallow</td>
<td>-</td>
<td>10 1</td>
</tr>
<tr>
<td>Wax</td>
<td>-</td>
<td>8 3</td>
</tr>
<tr>
<td>Spermaceti</td>
<td>-</td>
<td>6 4</td>
</tr>
<tr>
<td>Sperm oil (Carcel’s lamp)</td>
<td>-</td>
<td>3 0</td>
</tr>
<tr>
<td>London gases:</td>
<td>City</td>
<td>Great Central</td>
</tr>
<tr>
<td></td>
<td>Imperial</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Chartered</td>
<td>-</td>
</tr>
<tr>
<td>Western</td>
<td>-</td>
<td>3 0</td>
</tr>
<tr>
<td>Manchester gas</td>
<td>-</td>
<td>4 0</td>
</tr>
</tbody>
</table>

Notwithstanding the great economy and convenience attending the use of gas, and, in a sanitary point of view, the high position which, as an illuminating agent, coal-gas of proper composition occupies, its use in dwelling-houses is still extensively objected to. The objections are partly well founded and partly groundless. As is evident from the foregoing table, even the worst gases produce, for a given amount of light, less carbonic acid and heat than either lamps or candles. But then, where gas is used, the consumer is never satisfied with a light equal in brilliancy only to that of lamps or candles, and consequently, when three or four times the amount of light is produced from a gas of bad composition, the heat and atmospheric deterioration greatly exceed the corresponding effects produced by the other means of illumination. There is nevertheless a real objection to the employment of gas-light in apartments, founded upon the production of sulphurous acid during its combustion; this sulphurous acid is derived from bisulphuret of carbon, and the organic sulphur compounds, which have already been referred to as incapable of removal from the gas by the present methods of purification.

These impurities, which are encountered in almost all coal-gas now used, are the principal if not the only source of the unpleasant symptoms experienced by many sensitive persons in rooms lighted with gas. It is also owing to the sulphurous acid generated during the combustion of these impurities that the use of gas is found to injure the bindings of books, and impair or destroy the delicate colors of tapestry. Therefore the production of gas free from these noxious sulphur compounds is at the present moment a problem of the highest importance to the gas manufacturer, and one which demands his earnest attention.

The high sanitary position which gas takes, with regard to the production of a minimum amount of carbonic acid and heat for a given amount of light, ought to stimulate the manufacturer to perfect the process, by removing all sulphur compounds, and attaining the most desirable composition, so that this economical, and, if pure, agreeable and sanitary light, may contribute to our domestic comfort to a much greater extent than it has hitherto done.

HYDROCARBON GAS.

This title has been given to illuminating gas manufactured according to a patent granted some years ago to Mr. White of Manchester. The process of manufacture consists essentially in the generation of non-illuminating combustible gases by the action of steam upon
COAL-GAS.

Charcoal, coke, or other deoxidizing substances, in a separate retort, and the introduction of these gases, technically called water-gas, into the retort in which the illuminating gases are being generated, and in such a manner that these latter gases shall be swept out of the retort as rapidly as possible, so as to remove them from the destructive influence of a high temperature.

The retorts used for the hydrocarbon-gas process may be of various shapes and sizes. The settings are similar to those for the ordinary retorts, and any number which is necessary may be placed in an oven. They differ only from the ordinary retorts by having a horizontal partition, or diaphragm, cast in the centre, dividing the retort into two chambers, and extending to within 12 inches of the back. This diaphragm is found in practice to strengthen the sides of the retorts, and thus to add to their durability. The water-gas retorts may be cast from the same pattern as the cannel retorts, and may be set in exactly the same manner. Figs. 193a and 194 represent a setting of two retorts in one oven, and show the same in elevation, transverse section, and longitudinal section. The retorts here shown have an internal cubic capacity of about 16 feet, and the bed of two is capable of producing about 10,000 cubic feet per diem of hydrocarbon gas. The temperature at which the retorts are worked is about the average. The water-gas is generated in the retort A in the following manner:—The upper and lower chambers are well filled with coke or charcoal, and a very fine stream, or rapid drops, of water flowing from the tap enters the upper chamber through the siphon pipe, falling into a small steam-generating tube, which is placed inside to receive it, and instantly converts it into steam. The steam, in passing backwards along the upper chamber, and forwards along the lower one, becomes to a great extent decomposed into hydrogen, carbonic oxide, and carbonic acid gases. The water-gas generated in the retort A, as described above, enters the lower chamber of the retort B, through the connecting pipe C C, cast on the mouthpiece. In the chambers of this retort the illuminating gas is generated, either from coal, cannel, resin, or other suitable material, and being rapidly carried forward by the current of water-gas, its illuminating principles are preserved from the destruction caused by prolonged contact with the incandescent surfaces in the retort, whilst at the same time its volume is increased. When very rich cannels or other
materials are used, two, three, or even four water-gas retorts are made to discharge their gas into the cannal retort.

The hydrocarbon process has hitherto been applied only to resin, coals, and cannels. The following is a brief summary of the results of a series of experiments made by Dr. Frankland on the manufacture of hydrocarbon resin gas: Each hundred weight of resin was dissolved by heat in 7½ gallons of the resin oil of a former working, and the liquid, whilst still hot, was run into one of the retorts, by means of a siphon tube, in a stream about the thickness of a crown-gall, whilst water-gas, generated in the second retort, was admitted as described above. The mixed gases were then made to stream through the usual form of condensing apparatus, and were afterwards compelled to pass successively through wet and dry lime purifiers before they reached the gas-holder. In order to secure a uniform mixture of the gas produced in each experiment, it was allowed to remain at rest in the gas-holder for at least twelve hours before a specimen was withdrawn for analysis.

In the following tables both the practical and analytical results are given.

I. Practical Results.

<table>
<thead>
<tr>
<th>Average evolution of Gas per hour</th>
<th>Materials Consumed.</th>
<th>Products Obtained.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>930</td>
<td>2 1 173</td>
</tr>
<tr>
<td>3rd</td>
<td>1,000</td>
<td>2 1 18</td>
</tr>
<tr>
<td>4th</td>
<td>-</td>
<td>2 0 17</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2 0 7</td>
</tr>
</tbody>
</table>

Average production of gas per ton of resin - - 32,890 cubic feet.
Average production of resin oil per ton of resin - - 70¾ gallons.
Illuminating power of average gas before purification, as ascertained by shadow test; 75 cubic feet per hour = light of one short six spermaceti candle.

II. Analytical Results.

<table>
<thead>
<tr>
<th>Composition of Gas before Purification.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Amount in Cubic Feet.</td>
</tr>
<tr>
<td>1st Exp.</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Hydrocarbons</td>
</tr>
<tr>
<td>Light carb. hydrogen</td>
</tr>
<tr>
<td>Hydrogen</td>
</tr>
<tr>
<td>Carbonic oxide</td>
</tr>
<tr>
<td>Carbonic acid</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>33409</td>
</tr>
</tbody>
</table>
Composition of Gas after Purification.

<table>
<thead>
<tr>
<th></th>
<th>1st Exp.</th>
<th>2d Exp.</th>
<th>3d Exp.</th>
<th>4th Exp.</th>
<th>Average.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbons</td>
<td>8:27</td>
<td>7:94</td>
<td>7:78</td>
<td>8:55</td>
<td>8:16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

Specific gravity of average gas before purification = 0.65886.

Dr. Frankland has also investigated the hydrocarbon process as applied to coals and cannels, and the following is a tabulated summary of his experimental results.

Summary of Experimental Results.

<table>
<thead>
<tr>
<th>Name of Coal</th>
<th>Cubic feet of Gas per ton.</th>
<th>Illuminating power per ton. in Sperm Candles.</th>
<th>Gain per ton by White's process.</th>
<th>Gain per cent, by White's process.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wigan Cannel, Ince Hall</td>
<td>10,000</td>
<td>16,120</td>
<td>4,816</td>
<td>6,445</td>
</tr>
<tr>
<td>Wigan do., Balaclava</td>
<td>10,440</td>
<td>15,900</td>
<td>4,156</td>
<td>5,920</td>
</tr>
<tr>
<td>Boghead Cannel</td>
<td>10,340</td>
<td>15,210</td>
<td>2,996</td>
<td>5,166</td>
</tr>
<tr>
<td>Ditto, 3d experiment</td>
<td>10,620</td>
<td>15,120</td>
<td>32,020</td>
<td>35,020</td>
</tr>
<tr>
<td>Lesmahago Cannel</td>
<td>10,820</td>
<td>15,180</td>
<td>7,620</td>
<td>10,984</td>
</tr>
<tr>
<td>Methill Cannel</td>
<td>10,560</td>
<td>23,600</td>
<td>2,926</td>
<td>5,646</td>
</tr>
<tr>
<td>Newcastle do., Ramsey</td>
<td>10,300</td>
<td>15,920</td>
<td>5,096</td>
<td>7,026</td>
</tr>
</tbody>
</table>

Table, showing the quantity of Coal or Cannel requisite for producing light equal to 1,000 Sperm Candles, each burning 10 hours at the rate of 120 grs. per hour.

<table>
<thead>
<tr>
<th>Name of Coal</th>
<th>Weight of Coal.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>By old process.</td>
</tr>
<tr>
<td>Wigan Cannel (Ince Hall)</td>
<td>465 lbs.</td>
</tr>
<tr>
<td>Wigan Cannel (Balaclava)</td>
<td>639 lbs.</td>
</tr>
<tr>
<td>Boghead Cannel</td>
<td>197 lbs.</td>
</tr>
<tr>
<td>Lesmahago Cannel</td>
<td>293 lbs.</td>
</tr>
<tr>
<td>Methill Cannel</td>
<td>421 lbs.</td>
</tr>
<tr>
<td>Newcastle Cannel</td>
<td>445 lbs.</td>
</tr>
<tr>
<td>Newcastle Coal (Pelton)</td>
<td>745 lbs.</td>
</tr>
</tbody>
</table>
COAL-GAS.

Table Showing the quantity of Gas requisite for producing light equal to 1000 Sperm Candles, each burning 10 hours at the rate of 120 grs. per hour.

<table>
<thead>
<tr>
<th>Name of Gas</th>
<th>Rate of Consumption per hour</th>
<th>Quantity of Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wigan Cannel (Ince Hall)</td>
<td>Cubic Feet</td>
<td>Cubic Feet</td>
</tr>
<tr>
<td>Ditto by White’s process</td>
<td>5</td>
<td>2263</td>
</tr>
<tr>
<td>Wigan Cannel (Balcarres)</td>
<td>5</td>
<td>2500</td>
</tr>
<tr>
<td>Ditto by White’s process</td>
<td>5</td>
<td>2512</td>
</tr>
<tr>
<td>Boghead Cannel</td>
<td>3</td>
<td>2618</td>
</tr>
<tr>
<td>Ditto by White’s process</td>
<td>3</td>
<td>1168</td>
</tr>
<tr>
<td>Ditto ditto, 2d experiment</td>
<td>5</td>
<td>1756</td>
</tr>
<tr>
<td>Lesmahago Cannel</td>
<td>4</td>
<td>2500</td>
</tr>
<tr>
<td>Ditto by White’s process</td>
<td>4</td>
<td>2094</td>
</tr>
<tr>
<td>Methill Cannel</td>
<td>5</td>
<td>1798</td>
</tr>
<tr>
<td>Ditto by White’s process</td>
<td>5</td>
<td>2381</td>
</tr>
<tr>
<td>Newcastle Cannel (Ramsey)</td>
<td>5</td>
<td>2014</td>
</tr>
<tr>
<td>Ditto by White’s process</td>
<td>5</td>
<td>2660</td>
</tr>
<tr>
<td>Newcastle Coal (Pelton)</td>
<td>5</td>
<td>3356</td>
</tr>
<tr>
<td>Resin Gas by White’s process</td>
<td>{ calculated from analysis }</td>
<td>{ ditto ditto }</td>
</tr>
<tr>
<td>Manchester Gas (June, 1851)</td>
<td>5</td>
<td>3443</td>
</tr>
<tr>
<td>City Company’s Gas (July 15, 1851)</td>
<td>5</td>
<td>3846</td>
</tr>
<tr>
<td>Great Central Company’s Gas, do.</td>
<td>5</td>
<td>3546</td>
</tr>
<tr>
<td>Chartered Company’s Gas do.</td>
<td>{ calculated from analysis }</td>
<td>{ ditto ditto }</td>
</tr>
<tr>
<td>Imperial Company’s Gas do.</td>
<td>ditto</td>
<td>4099</td>
</tr>
<tr>
<td>Western Company’s Gas do.</td>
<td>ditto</td>
<td>1588</td>
</tr>
</tbody>
</table>

Dr. Frankland thus sums up the advantages which he conceives to result from the application of the hydrocarbon process to coals and cannels:—

1. It greatly increases the produce in gas from a given weight of coal or cannel, the increase being from 46 to 290 per cent, according to the nature of the material operated upon.

2. It greatly increases the total illuminating power afforded by a given weight of coal, the increase amounting to from 12 to 108 per cent, being greatest when coals affording highly illuminating gases are used.

3. It diminishes the quantity of tar formed, by converting a portion of it into gases possessing a considerable illuminating power.

4. It enables us profitably to reduce the illuminating power of the gases produced from such materials as Boghead and Lesmahago cannels, &c., so as to fit them for burning without smoke and loss of light.

Mr. Barlow has also experimented upon this process of gas-making, and finds that a very considerable gain in total illuminating power results from its use.

Mr. Clegg’s investigation of this process showed, that whilst Wigan Cannel produces by the ordinary process of gas-making about 10,000 cubic feet of 20 candle gas per ton, 16,000 cubic feet of 20 candle gas, or 26,000 cubic feet of 12 candle gas can be made from the same quantity of material by the hydrocarbon process. Also that, by the application of the same process to Lesmahago Cannel, 26,000 cubic feet of 20 candle gas, or 58,000 cubic feet of 12 candle gas per ton, can be obtained; whilst Boghead Cannel yields 32,000 cubic feet of 20 candle gas, or 75,000 cubic feet of 12 candle gas. The following table presents in a condensed form Mr. Clegg’s results as to comparative cost:—

<table>
<thead>
<tr>
<th>Name of Coal</th>
<th>Cost of 1000 feet of 20 candle gas by old process</th>
<th>Cost of 1000 feet of 20 candle gas by hydrocarbon process</th>
<th>Cost of 1000 feet of 12 candle gas by hydrocarbons process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wigan Cannel at 14s. per ton</td>
<td>1 s. 3d.</td>
<td>1 s. 8d.</td>
<td>0 11s.</td>
</tr>
<tr>
<td>Lesmahago Cannel at 18s. per ton</td>
<td>2 5s.</td>
<td>0 11s.</td>
<td>0 2s.</td>
</tr>
<tr>
<td>Boghead Cannel at 20s. per ton</td>
<td>2 4s.</td>
<td>0 11.</td>
<td>0 2s.</td>
</tr>
</tbody>
</table>
COAL-GAS.

Wood Gas.

Attempts were first made in France towards the close of the last century to manufacture an illuminating gas from wood. The Thermolamp of Lebon, a wood-gas apparatus, then and for some time afterwards excited considerable attention, especially in the districts of Germany, Sweden, and Russia, where coals are scarce. This mode of illumination proved, however, to be a complete failure, owing to the very feeble illuminating power of the gas produced, and as at this time the production of gas from coal was rapidly becoming better known, any thing like a regular manufacture of wood-gas never in any case gained a footing. Subsequent trials only confirmed the failure of Lebon, so that it was universally considered impossible to produce a practically useful gas from wood by the usual process of gas-manufacture. In the year 1842, Professor Pettenkofer of Munich had occasion to repeat these experiments, and he found that the gases evolved from wood at the temperature at which it carbonizes, consist almost entirely of carbonic acid, carbonic oxide, and light carburetted hydrogen; olefiant gas and the illuminating hydrocarbons being entirely absent. Such gas was therefore totally unfitted for illuminating purposes.

The temperature of boiling quicksilver, at which coal is not in the slightest degree decomposed, is quite sufficient to carbonize wood completely. If small pieces of wood be placed in a glass retort half filled with mercury, and the latter be heated to boiling, a black lustrous charcoal is left in the retort, whilst gas of the following composition is evolved:

- Carbonic acid
- Carbonic oxide
- Light carburetted hydrogen

The illuminating value of the hydrocarbons was found to be one-half greater than that of an equal volume of olefiant gas.

Varieties of wood differing so much in character as pine and beech were found to yield equally good gas. These observations prove that wood-gas is indubitably entitled to rank amongst illuminating agents.

With regard to the apparatus employed, various forms have been contrived so as to communicate the necessary temperature to the escaping vapors: it has been however at length found that the ordinary form of retort furnishes the necessary conditions, provided it be not filled more than one-third with the charge of wood. 120 lbs. of the latter, thoroughly dried, constitute the charge for one retort. In 1½ hours the distillation is complete, the result being, after absorption of carbonic acid, 650 cubic feet of gas, which is perfectly free from all sulphur and ammonia compounds, and possesses, according to the numerous experiments of Liebig and Steinheil, an illuminating power greater than coal-gas in the proportion of 5 : 3.

The following analyses show the composition of wood-gas when made on a manufacturing scale. No. 1 is a sample of gas before purification from the works at the Munich Railway Station, and No. 2 is purified gas, as supplied to the town of Bayreuth:

| Hydrocarbons | 6.91 | 9.74 | 11.23 |
| Light carburetted hydrogen | 11.06 | 9.45 |
| Hydrogen | 13.07 | 18.43 |
| Carbonic oxide | 40.59 | 61.79 |
| Carbonic acid | 25.72 | 22.21 |
| Nitrogen | 7.10 | 99.95 |

The specific gravity of the purified wood-gas is about 700, and this, coupled with the large percentage of carbonic oxide which it contains, renders it necessary to employ burn-
COCHINEAL.

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era with much larger performances than those used for coal-gas; in fact, if wood-gas be consumed at the rate of from 3 to 4 cubic feet per hour from a coal-gas burner, it yields scarcely any light at all, whereas if consumed from a fish-tail burner with wide apertures, its illuminating power exceeds, as just stated, that of coal-gas.

Although the relative cost of wood and coal will prevent the adoption of Professor Pettenkofer’s ingenious process in this country, yet, as it can also be applied with like results to peat, there is a high probability that it might be employed with great advantage in Ireland. Its rapid adoption in many German and Swiss towns proves the practicability of the process in districts where wood is cheap.—E. F.

COAL NAPTHA. See NAPHTHA (Coal.)

COBALT BLUE, or THENARD’S BLUE, is prepared by precipitating a solution of sulphate or nitrate of cobalt by phosphate of potash, and adding to the resulting gelatinous deposit from three to four times its volume of freshly deposited alumina, obtained by the addition of carbonate of soda to a solution of common alum. This mixture, after being well dried and calcined in a crucible, affords, when properly ground, a beautiful blue pigment.

COCHINEAL. In order to ascertain the value of cochineal for dyeing, we must have recourse to comparative experiments. We are indebted to M. Robiquet and Anthon for two methods of determining the quality of cochineals, according to the quantity of carmine they contain. The process of M. Robiquet consists in decolorizing equal volumes of decoction of different cochineals by chlorine. By using a graduated tube, the quality of the cochineal is judged of by the quantity of chlorine employed for decolorizing the decoction. The process of M. Anthon is founded on the property which the hydrate of alumina possesses of precipitating the carmine from the decoction so as to decolorize it entirely. The first process, which is very good in the hands of a skilful chemist, does not appear to us to be a convenient method for the consumer; in the first place, it is difficult to procure perfectly identical solutions; in the next place, it is impossible to keep them a long time without alteration. We know that chlorine dissolved in water reacts, even in diffuse light, on this liquid; decomposes it, appropriates its elements, and gives rise to some compounds which possess an action quite different from that of the chlorine solution in its primitive state. The second process seems to us to be preferable, as the proof liquid may be kept a long while without alteration. A graduated tube is also used; each division represents one-hundredth of the coloring matter. Thus the quantity of proof liquid added exactly represents the quantity in hundredths of coloring matter contained in the decoction of cochineal which has been submitted to examination. The following remarks from a practical dyer are valuable:

"The coloring matter of cochineal being soluble in water, I have used this solvent for exhausting the different kinds which I have submitted to examination in the colorimeter. I operated in the following manner:—I took a grain of each of the cochineals to be tried, dried at 122° Fahr.; I submitted them five consecutive times to the action of 200 grains of distilled water at water-bath heat, each time for an hour; for every 200 grains of distilled water I added two drops of a concentrated solution of acid sulphate of alumina and of potash. This addition is necessary to obtain the decoctions of the different cochineals exactly of the same tint, in order to be able to compare the intensity of the tints in the colorimeter."

"In order to estimate a cochineal in the colorimeter, two solutions, obtained as described above, are taken; some of these solutions are introduced into the colorimetric tubes as far as zero of the scale, which is equivalent to 100 parts of the superior scale; these tubes are placed in the box, and the tint of the liquids enclosed is compared by looking at the two tubes through the eye-hole; the box being placed so that the light falls exactly on the extremity where the tubes are. If a difference of tint is observed between the two liquids, water is added to the darkest (which is always that of the cochineal taken as type) until the tubes appear of the same tint."

"The number of parts of liquor which are contained in the tube to which water has been added is then read off; this number, compared with the volume of the liquor contained in the other tube, a volume which has not been changed, and is equal to 100, indicates the relation between the coloring power and the relative quality of the two cochineals. And if, for instance, 60 parts of water must be added to the liquor of good cochineal, to bring it to the same tint as the other, the relation of volume of the liquids contained in the tubes will be in the case as 180 is to 100, and the relative quality of the cochineals will be represented by the same relation, since the quality of the samples tried is in proportion to their coloring power".—(Napier.

* Care must be taken not to add to the water, which serves to extract the coloring matter from the different cochineals, more than the requisite quantity of acid sulphate of alumina and solution of potash, because a stronger dose would precipitate a part of the coloring matter in the state of lake.

* For diluting the same water must always be used which has served to extract the coloring matter of the cochineals under examination, otherwise the darkest decoction would pass into violet, as water was added to it, to bring back the tint to the degree of intensity as that of the decoction to which it is compared.
COCK-METAL.

The exports from Guatemala consist principally of cochinil, the staple and almost the only article of exportation for a number of years past. It is chiefly produced in Old Guatemala, nine leagues distant from Guatemala, and also in Amatellan, about six leagues distant. The raising of this insect is subject to so many accidents and contingencies that it is excessively precarious, and, above all, the weather has a great effect upon it. Taking all this into consideration, it is surprising that attention has not been directed to the cultivation and production of other articles suited to the climate and soil of Guatemala, and less liable to destruction by unseasonable rains and atmospheric changes than cochinil. It is reasonably to be feared that, if a longer time be suffered to pass, the cochillean of this country cannot compete with that of Teneriffe, and other parts of the world, where it is now beginning to be cultivated with success; and, should this happen, it would tend to diminish the trade of this country with England.

COCK-METAL. An inferior metal; a mixture of copper and lead used for making cocks. See Alloy.

COD-LIVER. The oil obtained from the livers of several varieties of the Gadidae family; especially from the torsk, Brosmea brosme. It is administered medicinally: it acts mainly as a nutritive body, and the old idea that its medicinal value depended on the iodine it contained is now proved to be false, since it holds no iodine in composition. Since the demand for cod-liver oil has been large, it has been extensively adulterated with other fish oils.

CODILL A OF FLAX. The coarsest parts of the fibre sorted out by itself. See Flax.

COIR. The outer coating of the cocoa-nut, often weighing one or two pounds, when stripped off longitudinally, furnishes the fibre called by the native name of Coir, and used for small cables and rigging.

In England these fibres are used in matting and for coarse brush work. In Price & Co.'s works they are advantageously employed, placed between iron trys and on the surface of the cocoa-nut and other concrete oils and fats, and subjected to great pressure; the liquid oil flows out, leaving solid fats behind. From the abundance, cheapness, and durability of this substance, it is likely to come into more general use, and it is even now very seriously proposed as a material for constructing Ocean Telegraphs; from its lightness and power of resisting sea-water. The qualities of coir for many purposes have been established for ages in the East Indies. Dr. Gilchrist thus describes the properties of coir ropes. "They are particularly elastic and buoyant, floating on the surface of the sea; therefore, when, owing to the strength of the current, a boat misses a ship, it is usual to veer out a quantity of coir, having previously fastened an oar, or small cask, &c., to its end. Thus the boat may be easily enabled to haul up to the ship's stern. Were a coir hawser," he adds, "kept on board every ship in the British Marine, how many lives would probably be saved." It is stated that fresh water rots coir in a very short time, corroding it in a surprising degree, whereas salt water absolutely strengthens it, seeming to increase the elasticity. Coir is therefore unfit for running rigging, especially for vessels subject to low latitudes, it being easily snapped in frosty weather.

Nothing can equal the ease with which a ship rides at anchor, when her cables are of coir. As the surges approach the bows, the vessel gradually recedes in consequence of the cable yielding to their force; but as soon as they have passed, it contracts again, drawing the vessel gradually back to her first position: the lightness of the material adds to this effect, for the cable would float if the anchor did not keep it down. At the present time the forces exerted upon cables and the angles assumed under different circumstances, in paying out submarine telegraphic cables, have been the subject of practical attention and theoretical investigation. Some of the greatest authorities have assumed that the forces exerted, between the bottom of the sea and the ship's stern, had reference only to forms or waves of the cables, representing some curve between the vertical and horizontal line, but always concave to the water surface. For a curve to exist, in the opposite direction, was named only as a condition, without evidence of any practical kind to show that it really existed, or called for any attention to investigate it. So long since, however, as 1835, Dr. Gilchrist, among others, had described this very opposite curve of the coir, viz.—of being, when in action as a cable, curved with a concave surface toward the bottom of the sea; a fact well known to the experienced sailors of England, as well as to the natives who employ these coir cables so extensively on the East Indian coast.

A hempen cable always makes a curve downward, between the vessel and the anchor, but a coir cable makes the curve upward. Therefore, if a right line were drawn from the
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hawse-hole, to the ring of the anchor, it would be something like the axis of a paraboloid spindle, of which the cables would form, or nearly so, the two elliptic segments."

In the employment of materials for ocean telegraphs, especially for deep-sea purposes, the use of iron and the proposal for using coal and other light substances, have caused the telegraphic means to be spoken of as "heavy" or "light" cables. Dr. Allan, of Edinburgh, proposes the abundant use of coal to make a light cable, say half the weight of the lightest hitherto made, the Atlantic cable. He states that a deep-sea cable may be compounded to weigh not more than 10 cwt. per mile: while the cheapness, durability in salt water, lightness, and abundant supply, will give it advantages over gupta percha and other substances used to form the bulk of the lightest cables hitherto employed.

When cocoanuts are sawed into two equal parts across the grain of the cork coating, they form excellent table brushes, causing wood planks to assume a very high polish by friction. If the shell should be left, the edges should be perfectly smooth, and then they will not scratch. It is a good mode to strip off the coal, and, after soaking it in water, to beat it with a heavy wooden mall until the pieces become plant, when they should be firmly bound together with an iron ring; the ends being levelled, the implement is fit for use: a little beeswax, rubbed occasion on them, adds greatly to the lustre of the furniture; of course, the polish is mainly due to strength and rapid action producing the friction upon the wood, and other articles of furniture.

In India, the coarse bark of the nuts is extensively used to cleanse houses, and washing the decks of vessels. Coarse stuff, matting, and bagging are made of the fibres, as well as ropes, sails, and cables.

The general preparation is simple; the fibrous husks or coats which envelop the cocoanuts, after being for some time soaked in water, become soft; they are then beaten to separate other substances with which they are mixed, which fall away like saw-dust, the strings or fibres being left; this is spun into long yarns, woven into sail-cloth, and twisted into cables, even for large vessels. Cordage thus made is considered preferable, in many respects, to that brought from Europe, especially the advantage of floating in water.

On burning the ligneous envelope of the cocoanut, an empyreumatic oil is obtained by the inhabitants of the island of Sumatra, and used by them for staining the teeth; and a light velvet-like carbon which is found useful in painting.

COKE. (Eng. and Fr.; Abjeschoderfelte, Germ.) It is necessary to distinguish between what is called gas-coke and oven-coke. The word coke applies, properly, to the latter alone; for, in a manufacturing sense, the former is merely cinder. The production of good coke requires a combination of qualities in coal not very frequently met with; and hence first-rate cooking coals can be procured only from certain districts. The essential requisites are, first, the presence of very little earthy or incombustible ash; and, secondly, the more or less insusceptibility of that ash. The presence of any of the salts of lime is above all objectionable; after which may beclassed silica and alumina; for the whole of these have a strong tendency to produce a vitreous fusion, or slag, upon the bars of the furnace in which the coke is burnt; and in this way the bars are speedily corroded or burnt out; whilst the resulting cinders impedes or destroys the draught, by fusing over the interstices of the bars or air-passages. Iron pyrites is a common obstacle to the coke maker; but it is found in practice, that a protracted application of heat in the oven dissipates the whole of the sulphur from the iron, with the production of bisulphuret of carbon and metallic carburet of iron, the latter of which alone remains in the coke, and, unless silica be present, has no great disposition to vitrify after oxidation. Where the iron pyrites exists in large quantities, it is separated by the coal-washing machines, some of which will be described in a general article.—See WASHING MACHINES. One object, therefore, gained by the oven-coke manufacturer over the gas maker, is the expulsion of the sulphuret of carbon, and consequent purification of the residuary coke. Another, and a still more important consequence of a long-sustained and high heat is, the condensation and contraction of the coke into a smaller volume, which, therefore, permits the introduction of a much greater weight into the same space—an advantage of vast importance in blast furnaces, and, above all, in locomotive engines, as the repeated introduction of fresh charges of coal fuel is thus prevented. Part of this condensation is due to the weight of the superincumbent mass of coal thrown into the coke-oven, by which (when the coal first begins to cake or fuse together) the particles are forced towards each other; and the cavernous character of cinder got rid of; but the chief contraction arises, as we have said, from the natural quality of carbon, which, like alumina, goes on contracting, the longer and higher the heat to which it is exposed. Hence, good coke cannot be made in a short time; and that used in locomotive engines is commonly from 48 to 96, or even 120 hours in the process of manufacture.

The prospects of improvement in coke-making point rather to alterations in the oven than in the process. Formerly it was not thought possible to utilize the heat evolved by the gaseous constituents of the coal; but now, as an example of the correctness of this idea, it may be stated that at the Felling Chemical Works, 200 tons of salt per week are made by the waste heat alone, and it is also employed in partially heating the blast for our
of the furnaces. There appears no valid reason why sets of coke-ovens might not be so arranged as mutually to compensate for each other, and produce upon one particular flue a constant and uniform effect. Contrivances of this kind have been projected,—but hitherto, we may suppose, without uniform success, as many of our large coke-makers still continue the old mode of working.

Mr. Ebenezer Rogers, of Abercarn, in Monmouthshire, has lately introduced a new method of coking, which he thus describes:

"A short time ago a plan was mentioned to the writer as having been used in Westphalia, by which wood was charred in small kilns: as the form of kiln described was quite new to him, it led him to some reflection as to the principles on which it acted, which were found to be so simple and effective, that he determined to apply them on a large scale for coking coal. The result has been that in the course of a few months the original idea has been so satisfactorily matured and developed, that instead of coking 6 tons of coal in an oven costing £80, 150 tons of coal are now being coked at once in a kiln costing less than the former single oven.

"Figs. 195 and 196 are a side elevation and plan of one of the new coking kilns to a small scale; fig. 197 is an enlarged transverse section.

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"B D are the walls of the kiln, which are provided with horizontal flues, \( K, F \), which open into the side or bottom of the mass of coal. Connected with each of these flues are the vertical chimneys \( G H \). The dotted lines 1, 1, fig. 196, represent a movable railway, by which the coal may be brought into the kiln and the coke removed from it. In filling the kiln with coal, care is taken to preserve transverse passages or flues for the air and gases between the corresponding flues \( K, F \) in the opposite walls. This is effected by building or constructing the passages at the time with the larger pieces of coal, or else by means of channels or flues permanently formed in the bed of the kiln. When the coal is of different sizes, it is also advantageous to let the size of the pieces diminish towards the top of the mass. The surface of the coal, when filled in, is covered with small coal, ashes, and other suitable material.

"When the kiln is filled, the openings \( K \) at the ends are built up with bricks, as shown dotted; the kiln is not covered by an arch, but left entirely open at the top. The apertures of the flues \( F \) and the chimneys \( G \) are then closed, as shown in fig. 197, and the coal is ignited through the flues \( K \); the air then enters the flues \( F \) and passes through the coal, and then ascends the chimneys \( H \), as shown by the arrows. When the current of air has proceeded in this direction for some hours, the flues \( K \) and chimneys \( H \) are closed, and \( F \) and \( G \) are opened, which reverses the direction of the current of air through the mass. This alternation of the current is repeated as often as may be required. At the same time
COKE.

air descends through the upper surface of the mass of coal. When the mass is well ignited, which takes place in from 24 to 36 hours, the external apertures of the flues $k$ and $f$ are closed, and the chimneys $g$ and $h$ opened: the air now enters through the upper surface of the coal only, and descends through the mass of the coal, the products of combustion passing up the chimneys.

The coking gradually ascends from the bottom of the mass to the top, and can be easily regulated or equalized by opening or closing wholly or partially the apertures of the flues or chimneys. The top surface of the coal being kept cool by the descending current of air, the workman is enabled to walk over it during the operation; he inserts from time to time at different parts of the surface an iron bar, which is easily pushed down till it reaches the mass of coke, by which its further descent is prevented. In this way the workman gauges the depth at which the coking process is taking place, and if he finds it to have progressed higher at one part than at another, he closes the chimneys communicating with that part, and thus retards the process there. This gaging of the surface is carried on without difficulty until the coking process has arrived close to the top. The gases and tarry vapors produced by the distillation or combustion descend through the interstices of the incandescent mass below, and there deposit a portion of the carbon contained in them, the residual gases passing up the chimneys. The coke at the lower part of the kiln is effectually protected from the action of the air, by being surrounded and enveloped in the gases and vapors which descend through it, and are non-supporters of combustion.

When the mass of coal has been coked up to the top, which takes place in about seven days, it is quenched with water, the walls closing the end openings $k$ are taken down, and the coke is removed. When a portion has been removed, a movable railway is laid in the kiln, so as to facilitate the removal of the remainder of the coke.

The flues $k$ and $f$ may enter at the bottom of the kiln, or at the sides above the bottom, as in fig. 197; in the latter case the space below, up to the level of the bottom of the flues, may be filled with small coal, which becomes coked by the radiated heat from the incandescent mass above. The transverse passages through the mass are then constructed upon this bed of small coal with the larger lumps of coal, as before mentioned. The flues and chimneys need not necessarily be horizontal and vertical; and instead of connecting a separate chimney with each transverse flue, flues may be constructed longitudinally in the walls of the kiln, so as to connect two or more of the transverse flues, which are then regulated by dampers, conveying the gaseous products from them into chimneys of any convenient height; the arrangement first described, however, and shown in the drawings, is preferred. The gaseous products may be collected, and tar and ammonia and other chemical compounds manufactured from them by the usual modes. The coking or charring of peat and wood may be effected in a similar manner to that already described with regard to coal.

The new kilns have proved entirely successful; they are already in use at some of the largest iron works in the kingdom, and are being erected at a number of other works. The great saving in first cost of oven, economy in working and maintenance, increased yield, and improved quality of coke, will probably soon cause this mode of coking to supersede the others now in use. The kilns are most advantageously made about 14 feet in width, and 90 feet in length, and 7 feet 6 inches in height; this size of kiln contains about 150 tons of coal.

From the long experience of this gentleman, we are induced to quote yet further from his memoir:

The process of coking converts the coal into a porous mass; but this is done during the melting of the coal, at which moment the gases in liberating themselves form very minute bubbles; but the practical result is the same as in wood coal, allowing a large surface of carbon in a small space to be acted upon by the blast. As a general rule, coke made rapidly has larger pores and is lighter than coke made slowly; it accordingly bears less blast, and crumbles too easily in the furnace.

The process of coking in the ordinary ovens may be thus explained: When the oven is filled with a proper charge, the coal is fired at the surface by the radiated heat from the roof; enough air is admitted to consume the gases given off by the coal, and thus a high temperature is maintained in the roof of the oven. The coal is by this means melted; and those portions of it which, under the influence of a high temperature, can of themselves form gaseous compounds, are now given off, forming at the moment of their liberation small bubbles or cells; the coke now left is quite safe from waste, unless a further supply of air is allowed to have access to it. At this stage of the process, the coke assumes a pentagonal or five-sided shape, and columnar structure. When the coke is left exposed to heat for some time after it is formed, it becomes harder and works better, from being less liable to crush in the furnace and decrepitate on exposure to the blast.

It is a strange fact, that the hotter the oven the better the yield of coke; hence all the arrangements of flues to keep up the temperature of the ovens. This fact is however the result of laws well known to chemists. When the coal is melted as
above mentioned, the hydrogen in the coal takes up two atoms of carbon for each two atoms of hydrogen, forming bicarburetted hydrogen gas, \((\text{CH}_2\text{H})_2\) this at once escapes, but it has to pass upwards through the red-hot coke above, which is at a higher temperature than the melted coal below. Now when bicarburetted hydrogen gas is exposed to a bright-red heat, it is decomposed, forming carburetted hydrogen gas, \((\text{CH}_2\text{H})_2\) and depositing one atom, or one-half of its carbon, in a solid form. Consequently in the process of coking, if the oven is in good working order and the coke hot enough, the liberated carbon is detained in its passage upwards, and either absorbed by the coke, or crystallized per se upon it. This is simply illustrated by passing ordinary illuminating gas through a tube heated to a bright-red heat; the tube will soon become coated internally, and ultimately filled with a carbonaceous deposit produced by the decomposition of the bicarburetted hydrogen contained in the gas.

It is found that some coal which is too dry or not sufficiently bituminous to coke when put into the oven by itself in lumps, will coke perfectly if crushed small and well wetted with water and charged in this state. This fact, if followed out, would lead to an examination of the chemical nature of the effect produced by the water, and would point the way to further improvements.

"Charred Coal," as it is called, must be regarded as a species of coke. It has been largely employed in lieu of charcoal in the manufacture of tin plates. This preparation is also a discovery of Mr. Ebenezer Rogers, who thus describes its manufacture:—

The preparation of the "charred coal" is simple. The coal is first reduced very small, and washed by any of the ordinary means; it is then spread over the bottom of a reverberatory furnace to a depth of about four inches; the bottom of the furnace is first raised to a red heat. When the small coal is thrown over the bottom, a great volume of gases is given off, and much ebullition takes place: this ends in the production of a slight spongy mass, which is turned over in the furnace and drawn in a hour and a half. To completely clear off the sulphur, water is now freely sprinkled over the mass until all smell of the sulphuretted hydrogen produced ceases. Charred coal has been hitherto produced on the floor of a coke-oven, whilst red-hot, after drawing the charge of coke. See TIN PLATE MANUFACTURE.

A process has for some time been gaining ground in France known as the "Systeme Appolt," from its being introduced by two brothers of that name. The coking furnaces employed are vertical, and they are in compartments. The authors have published a description of their process and a statement of its results, "Carbonisation de la Houille Systeme Appolt, decid par les Auteurs, M.M. Appolt Freres?" Paris, 1868, to which we must refer our readers.

COLLIDINE. \(\text{CH}_2\text{N}_2\). A volatile base discovered by Anderson in bone oil, and subsequently found in shale naphtha, in the basic fluid obtained by acting on cinchonine with potash, and in common coal naphtha. Its density is 0.921, and its boiling point, 354°.

C. G. W.

COLORING MATTERS. The color of any object, either natural or artificial, owes its origin to the effect produced on it by the rays of light. This effect is either due to the mass or substance of the body itself, as may be seen in the colors of metals and many shells, or it arises from the presence of some foreign substance or substances not absolutely essential to it, and which may in many cases be separated and removed from it. It is in speaking of these foreign substances, which are often found coloring natural objects, or which are employed in the arts for the purpose of imparting colors to various materials, that we generally make use of the term coloring matter. By chemists, however, the term is only applied to organic bodies and not to mineral substances, such as oxide of iron, cinabar, ultramarine, &c., which, though they are employed as pigments in the arts, differ very widely in their properties from one another and from coloring matters in the narrower sense of the word. Coloring matters may be defined to be substances produced in animal or vegetable organisms, or easily formed there by processes occurring in nature, (such as oxidation or fermentation,) and which are either themselves colored or give colored compounds with bases or with animal or vegetable fibre. According to this definition, bodies like carbazotic acid and murexide, which are formed by complicated processes such as never occur in nature, are excluded, though they resemble true coloring matters in many of their properties, such as that of giving intensely colored compound bases. Whether, however, even after accepting the above definition, coloring matters can be considered as constituting a natural class of organic bodies, such as the fats, resins, &c., must still remain doubtful, though modern research tends to prove that these substances are related to one another by other properties besides the accidental one of color, and will probably be found eventually to belong in reality to one natural class.

Coloring matters occur in all the organs of plants, in the root, wood, bark, leaves, flowers, and fruit; in the skin, hair, feathers, blood, and various secretions of animals; in insects, for example, in various species of coeexus; and in mollusca, such as the nurex. Indeed, there are very few plants or animals whose organs do not produce some kind of
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coloring matter. It is remarkable, however, that the colors which are most frequently presented to our view, such as those of the leaves and flowers of plants and the blood of animals, are produced by coloring matters with which we are but very little acquainted, the coloring matters, which to the artist, and which have been examined with most care, but almost all cases the preparation of coloring matters in a state of purity presents great difficulties, so that it may even be said that very few are known in that state.

Some coloring matters bear a great resemblance to the so-called extractive matters, others to resins. Hence they have been divided into extractive and resinous coloring matters. These resemblances are however of no great importance. The principal coloring matters possess such peculiar properties that they must be considered as bodies altogether sui generis.

As regards their most prominent physical characteristic, coloring matters are divided into three principal classes, viz., the red, yellow, and blue, the last class comprising the smallest number. Only one true green coloring matter occurs in nature, viz., chlorophyll, the substance to which the green color of leaves is owing.* Black and brown coloring matters are also uncommon, the black and brown colors obtained in the arts from animals or vegetables being (with the exception of sepia and a few others) compounds of coloring matters with bases. The colors of natural objects are often due to the presence of more than one coloring matter. This may easily be seen in the petals of some flowers. If, for instance, the petals of the orange-flowered variety of the Tropaeolum majus be treated with boiling water, a coloring matter is extracted which imparts to the water a purple color. The petals now appear yellow, and if they be treated with boiling spirits of wine, a yellow coloring matter is extracted, and they then become white. When the purple coloring matter is absent, the flowers are yellow; when, on the contrary, it is present in greater abundance, they assume different shades of brown. Precisely the same phenomena are observed in treating the petals of the brown Calceolaria successively with boiling water and spirits of wine. In many cases coloring matters exhibit, when in an uncombined state, an entirely different color from what they do when they enter into a state of combination. The coloring matter of litmus, for instance, is, when uncombined, red, but its compounds with alkalies are blue. The alkaline compounds of alizarine are of a rich violet color, while the substance itself is reddish-yellow. Many yellow coloring matters become brown by the action of alkalis, and many of the coloring matters of flowers generally turn green when exposed to the same influence. The classification of coloring matters, according to color, is therefore purely artificial. The terms red, yellow, and blue coloring matter, merely signify that the substance itself possesses one of these colors, or that most of its compounds are respectively red, yellow, or blue. In almost all cases, even when the color is not entirely changed by combination with other bodies, its intensity is much increased thereby, substances of a pale yellow color becoming of a deep yellow, and so on.

Coloring matters consist, like most other organic substances, either of carbon, hydrogen, and oxygen, or of those elements in addition to nitrogen. The exact relative proportions of these constituents, however, is known in very few cases, and in still fewer instances have the chemical formulas of the compounds been established with any approach to certainty. This proceeds on the one hand from the small quantities of these substances usually present in the organs of plants and animals, and the difficulty of obtaining sufficient quantities for examination in a state of purity, and on the other hand from the circumstance of their possessing a very complex chemical constitution and high atomic weight.

Only a small number of coloring matters are capable of assuming a crystalline form; the greater number, especially the so-called resinous ones, being perfectly amorphous. Among those which have been obtained in a crystalline form, may be mentioned alizarine, indigo-blue, quercitrine, morina, luteoline, chrysophan, and rutine. It is probable, however, that when improved methods have been discovered of preparing coloring matters, and of separating them from the impurities with which they are so often associated, many which are now supposed to be amorphous will be found to be capable of crystallizing.

Very little is known concerning the action of light on coloring matters and their compounds. It is well known that these bodies, when exposed to the rays of the sun, especially when deposited in thin layers on or in fabrics made of animal or vegetable materials, lose much of the intensity of their color, and sometimes even disappear entirely—that is, they are converted into colorless bodies. But whether this process depends on a physical action induced by the light, or whether, as is more probable, it consists in promoting the decomposing action of oxygen and moisture on them, is uncertain. The most stable coloring matters, such as indigo-blue and alizarine in its compounds, are not insensible to the action of light. Others, such as carthamine from safflower, disappear rapidly when exposed to its influence.

* Another green coloring matter, derived from different species of Rhododendron, has lately been described under the name of "Chinese Green." It is stated to be a peculiar substance, not, as might be supposed, a mixture of a blue and a yellow coloring matter.

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the action of light better than those obtained from one alone. In one case, viz., that of
Tyrian purple, the action of light seems to be absolutely essential to the formation of the
coloring matter. The leaves of plants also remain colorless if the plants are grown in dark-
ness, though in this case the formation of the green coloring matter is probably not due to
the direct chemical action of the light.

The action of heat on coloring matters varies very much according to the nature of the
latter and the method of applying the heat. A moderate degree of heat often changes the
hue of a coloring matter and its compounds, the original color being restored on cooling—
an effect which is probably due to physical causes. Sometimes the coloring is, without doubt,
owing to the loss of water. Alizarine, for instance, crystallized from alcohol, when heated
212°F., loses its water of crystallization, its color changing at the same time from red-
dish-yellow to red. At a still higher temperature most coloring matters are entirely decom-
posed, the products of decomposition being those usually afforded by organic matters, such
as water, carbonic acid, carbonated hydrogen, empyreumatic oils, and, if the substance con-
tains nitrogen, ammonia, or organic bases such as aniline. A few coloring matters, as, for
example, alizarine, rubiaine, indigo-blue, and indigo-red, if carefully heated, may be vola-
tilized without change, and yield beautifully crystallized sublimates, though a portion of
the substance is sometimes decomposed, giving carbon and empyreumatic products.

Coloring matters, like most other organic substances, undergo decomposition with more
or less facility when exposed to the action of oxygen; and the process may, indeed, be
more easily traced, in their case, as it is always accompanied by a change of hue. Its effects
may be daily observed in the colors of natural objects belonging to the organic world.
Flowers, in many cases, lose a portion of their color before fading. The leaves of plants,
before they fall, lose their green color and become red or yellow. The color of venous
blood changes, when exposed to the air, from dark red to light red. When exposed to the
action of oxygen, blue and red coloring matters generally become yellow or brown, but the
process seldom ends here; it continues until the color is quite destroyed; that is, until the
substance is converted into a colorless compound. This may be easily seen when a fabric,
dyed of some fugitive color, is exposed to the air. The intensity of the color diminishes,
in the first instance; it then changes in hue, and, finally, disappears entirely. Indeed, the
whole process of bleaching in the air depends on the concurrent action of oxygen, light,
and moisture. The precise nature of the chemical changes which coloring matters undergo,
during this process of oxidation, is unknown. No doubt it consists, generally speaking, in
the removal of a portion of their carbon and hydrogen, in the shape of carbonic acid and
water, and the conversion of the chief mass of the substance into a more stable compound,
capable of resisting the further action of oxygen. But this statement conveys very little
information to the chemist, who, in order to ascertain the nature of a process of decomposi-
tion, requires to know exactly all its products, and to compare their composition with that
of the substances from which they are derived. The indeterminate and uninteresting nature
of the bodies into which most coloring matters are converted by oxidation, has probably
deterred chemists from their examination. The action of oxygen on coloring matters varies
according to their nature and the manner in which the oxygen is applied, and it is the de-
gree of resistance which they are capable of opposing to its action that chiefly determines
the stability of the colors produced by their means in the arts. Indigo-blue shows no tendency
to be decomposed by gaseous oxygen at ordinary temperatures; it is only when the
latter is presented in a concentrated form, as in nitric or chromic acid, or in a nascent state,
as in a solution of ferric cyanide of potassium containing caustic potash, that it undergoes
decomposition. When, however, indigo-blue enters into combination with sulphure acid,
it is decomposed by means of oxygen with as much facility as some of the least stable of
this class of bodies. Some coloring matters are capable of resisting the action of oxygen
even in its most concentrated form. Of this kind are rubiainine and rubiaine, which, when
mixed with boiling nitric acid, merely dissolve in the liquid, and crystallize out again when
the latter is allowed to cool. The action of atmospheric oxygen on coloring matters is gen-
erally promoted by alkalies, and retarded in the presence of acids. A watery solution of
hematite, when mixed with an excess of caustic alkali, becomes of a beautiful purple; but the
color, when exposed to the air, almost immediately turns brown, the hematite being
then completely changed. It is almost needless to observe, that the bodies into which
coloring matters are converted by oxidation, are incapable, under any circumstances, of
returning to their original state.

The action of reducing agents, that is, of bodies having a great affinity for oxygen, on
some coloring matters, is very peculiar. If indigo-blue, suspended in water, be placed in
contact with protoxide of iron, protoxide of tin, or an alkaline sulphuret, sulphite or phos-
phite, or grape sugar, or, in short, any easily oxidizable body, an excess of some alkali or
alkaline earth being present at the same time, it dissolves, forming a pale yellow solution
without a trace of blue. This solution contains, in combination with the alkali or alkaline
earth, a perfectly white substance, to which the name of reduced indigo has been applied.
When an excess of acid is added to the solution, it is precipitated in white flocks. By ex-
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posure to the air, either by itself or in a state of solution, reduced indigo rapidly attracts oxygen, and is reconverted into indigo-blue. Hence the surface of the solutions, if left to stand in uncovered vessels, becomes covered with a blue film of regenerated indigo-blue. It was for a long time supposed that reduced indigo was simply deoxidized indigo-blue, and that the process consisted merely in the indigo-blue parting with a portion of its oxygen, which was taken up again on exposure to the air. It has, however, been discovered, that in every case water is decomposed during the process of reduction which indigo-blue undergoes, the oxygen of the water combining with the reducing agent, and the hydrogen uniting with the indigo-blue, water being again formed when reduced indigo comes in contact with oxygen. Reduced indigo is therefore not a body containing less oxygen than indigo-blue, but is a compound of the latter with hydrogen. There are several red coloring matters which possess the same property, that of being converted into colorless compounds by the simultaneous action of reducing agents and alkalies, and of returning to their original state when exposed to the action of oxygen. There can be little doubt that the process consists, in all cases, in the coloring matter combining with hydrogen and parting with it again when the hydroyet comes in contact with oxygen.

The action of chlorine on coloring matters is very similar to that of oxygen, though, in general, chlorine acts more energetically. The first effect produced by chlorine, whether it be applied as free chlorine, or in a state of combination with an alkali, or alkaline earth as an hypochlorite, usually consists in a change of color. Blue and red coloring matters generally become yellow. By the continued action of chlorine, all trace of color disappears, and the final result is the formation of a perfectly white substance, which is usually more easily soluble in water and other menstrua than that from which it was formed. Since it is most commonly by means of chlorine or its compounds that coloring matters are destroyed or got rid of in the arts, as in bleaching fabrics and discharging colors, the process of decomposition which they undergo by means of chlorine has attracted a good deal of attention, and the nature of the chemical changes, which take place in the course of it, has often been made a subject of dispute, though the matter is one possessing more of a theoretical than a practical interest. It is a well-known fact, that many organic bodies are decomposed when they are brought into contact, in a dry state, with dry chlorine gas. The decomposition consists in the elimination of a portion of the hydrogen of the substance and its substitution by chlorine. When water is present at the same time, the decomposition is, however, not so simple. It is well known that chlorine decomposes water, combining with the hydrogen of the latter and setting its oxygen at liberty, and it has been asserted, that in the bleaching of coloring matters, that of chlorine when moisture is usually present, this always takes place in the first instance, and that it is in fact the oxygen which effects their destruction, not the chlorine. This appears, indeed, to be the case occasionally. Rubin, for instance, the body from which alizarine is derived, gives, when decomposed with chloride of lime, phthalic acid, a beautifully crystalized substance, containing no chlorine, which is also produced by the action of nitric acid on rubies, and is, therefore, truly a product of oxidation. In many cases, however, it is certain that the chlorine itself also enters into the composition of the new bodies produced by its action on coloring matters. When, for instance, chlorine acts on indigo-blue, chlorisatine is formed, which is indigo-blue, in which one atom of hydrogen is replaced by one of chlorine, plus two atoms of oxygen, the latter being derived from the decomposition of water.

The behavior of coloring matters towards water and other solvents is very various. Some coloring matters, such as those of logwood and brazillwood, are very easily soluble in water. Others, such as the coloring matters of madder and quercitron-bark, are only sparingly soluble in water. Many, especially the so-called resinous ones, are insoluble in water, but more or less soluble in alcohol and ether, or alkaline liquids. A few, such as indigo-blue, are almost insoluble in all menstrua, and can only be made to dissolve by converting them, by means of reducing agents, into other bodies soluble in alkalies. Those which are soluble in water, are, generally speaking, of the greatest importance in the arts, since they admit of more ready application when they possess this property.

The behavior of coloring matters towards acids, is often very characteristic. Most coloring matters are completely decomposed by nitric, chloric, manganic, and chromic acids, in consequence of the large proportion of oxygen which these acids contain. With many coloring matters the decomposition takes place even at the ordinary temperature; with others, it only commences when the acid is warmed, especially if the latter be applied in a state of considerable dilution. Concentrated sulphuric acid also destroys most coloring matters, especially if the acid be heated. It seems to act by depriving them of the elements of water, and thereby converting them into substances containing more carbon than before, as may be inferred from the dark, almost black color which they acquire. At the same time the acid generally loses a portion of its oxygen, since sulphurous acid is almost always evolved on heating. Some coloring matters, such as alizarine, are not decomposed by concentrated sulphuric acid even when the latter is raised to the boiling point; they merely dissolve, forming solutions of various colors, from which they are precipitated unchanged, on
the addition of water, when they are insoluble, or not easily soluble in the latter. Others, again, like indigo-blue, dissolve in concentrated or fuming sulphuric acid, without being decomposed, and at the same time enter into combination with the acid, forming true double acids, which are easily soluble in water, and combine as such with bases. Many coloring matters undergo a change of color when exposed to the action of acids, the original color being restored by the addition of an excess of alkalii, and this property is made use of for the detection of acids and alkalies. The color of an infusion of litmus, for instance, is changed by acids from blue to red, and the blue color is restored by alkalies. An infusion of the petals of the purple dahlia or of the violet becomes red on the addition of acids, and this red color changes again to purple or blue with alkalies, an excess of alkalii making it green. The yellow color of rutine becomes deeper with strong acids. In most cases, this alteration of color depends on a very simple chemical change. Litmus, for example, in the state in which it occurs in commerce, consists of a red coloring matter in combination with ammonia, the compound being blue. By the addition of an acid, the ammonia is removed, and the uncombined red coloring matter makes its appearance. Ammonia and most alkalies remove the excess of acid, and, by combining with the red coloring matter, restore the blue color. When a coloring matter, like alizarine, is only sparingly soluble in water, its solubility is generally diminished in the presence of a strong acid. Hence, by adding acid to the watery solution, a portion of the coloring matter is usually precipitated. It is very seldom that coloring matters are really found to enter into combination with acids. Indeed, only one, viz., berberine, is capable of acting the part of a true base, and forming definite compounds with acids. Some acids, such as sulphurous and hydro sulphuric acids, do certainly seem to combine with some coloring matters and form with them compounds, in which the color is completely disguised, and apparently destroyed. If a red rose be suspended in an atmosphere of sulphurous acid, it becomes white, but the red color may be restored by neutralizing the acid with some alkali. On this property of sulphurous acid depends the process of bleaching woollen fabrics by means of burning sulphur. In this case the coloring matter is not destroyed, but only disguised by its combination with the acid.

Most coloring matters are capable of combining with bases. Indeed, their affinity for the latter is generally so marked, that they may be considered as belonging to the class of weak acids. Like all other weak acids, they form, with bases, compounds of a very indefinite composition, so much so that the same compound, prepared on two different occasions, is often found to be differently constituted. Hence the great difficulty experienced by chemists in determining the atomic weight of coloring matters. There are very few of the latter for which several formulae, all equally probable, may not be given, if the compounds with bases be employed for their determination. The compound of coloring matters with bases hardly ever crystallizes. Those with alkalies are mostly soluble in water and amorphous; those with the alkaline earths, lime and baryta, are sometimes soluble, sometimes insoluble; those with the earths and metallic oxides are almost always insoluble in water. The compounds with alkalies are obtained by dissolving the coloring matter in water, to which a little alkali is added, and evaporating to dryness—an operation which must be carefully conducted if the coloring matter is one easily affected by oxygen. The insoluble compounds, with earths and metallic oxides, are obtained either by double decomposition of a soluble compound with a soluble salt of the respective base, or by adding to a solution of the coloring matter, in water or any other menstruum, a salt of the base containing some weak acid, such as acetic acid. It is remarkable, that of all bases, none show so much affinity for coloring matters as alumina, peroxide of iron, and peroxide of tin, bodies which occupy an intermediate position between acids and bases. If a solution of any coloring matter be agitated with a sufficient quantity of the hydrates of any of these bases, the solution becomes decolorized, the whole of the coloring matter combining with the base and forming a colored compound. It is accordingly these bases that are chiefly employed in dyeing, for the purpose of fixing coloring matters on particular portions of the fabric to be dyed. When used for this purpose, they are called mordants. Their compounds with coloring matters are denominated lakes, and are employed as pigments by painters. The colors of the compounds usually differ, either in kind or degree, from those of the coloring matters themselves. Red coloring matters often form blue compounds, yellow ones sometimes give red or purple compounds. The compounds with peroxide of iron are usually distinguished by the intensity of their color. When a coloring matter gives with alumina and oxide of tin red compounds, its compound with peroxide of iron is usually purple or black; and when the former are yellow, the latter is commonly olive or brown. Almost all the compounds of coloring matters with bases are decomposed by strong acids, such as sulphuric, muriatic, nitric, oxalic, and tartaric acids, and even acetic acid is not without effect on most of these compounds with earths and metals. The compounds with earths are also decomposed, sometimes, by alkalies. A solution of soap is sufficient to produce this effect in many cases, and dyes are therefore often tested by means of a solution of soap, in order to ascertain the degree of permanence which they possess.
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No property is so characteristic of coloring matters, as a class, as their behavior towards bodies of a porous nature, such as charcoal. If a watery solution of a coloring matter be agitated with charcoal, animal charcoal being best adapted for the purpose, the coloring matter is in general entirely removed from the solution and absorbed by the charcoal. The combination which takes place under these circumstances is probably not due to any chemical affinity, but is rather an effect of the so-called attraction of surface, which we often see exerted by bodies of a porous nature, such as charcoal and spongy platinum, and which enables the latter to absorb such large quantities of gases of various kinds. That the compound is indeed more of a physical than a chemical nature, seems to be proved by the circumstance that sometimes the coloring matter is separated from its combination with the charcoal by means of boiling alcohol, an agent which can hardly be supposed to exert a stronger chemical affinity than water. It is this property of coloring matters which is made use of by chemists to decolorize solutions, and by sugar manufacturers to purify their sugar.

The attraction manifested by coloring matters for animal or vegetable fibres, is probably also a phenomenon of the same nature, caused by the porous condition of the latter, and the powerful affinity of the so-called mordants for coloring matters, may, perhaps, be in part accounted for by their state of mechanical division being different from that of other bases. Coloring matters, however, vary much from one another in their behavior towards animal or vegetable fibres. Some, such as indigo-blue, and the coloring matters of safflower and turmeric, are capable of combining directly with the latter and imparting to them colors of great intensity. Others are only slightly attracted by them, and consequently impart only feeble tints; they therefore require, when they are employed in the arts for the purpose of dyeing, the interpolation of an earthy or metallic base. To the first class Bancroft applied the term substantive coloring matters, to the second that of affactive coloring matters.

One of the most interesting questions connected with the history of coloring matters, is that in regard to the original state in which these substances exist in the animal and vegetable organisms from which they are derived. It has been known for a long time that many dye-stuffs, such as indigo and archil, do not exist ready-formed in the plants from which they are obtained, and that a long and often difficult process of preparation is required in order to eliminate them. The plants which yield indigo exhibit, while they are growing, no trace of blue color. The coloring matter only makes its appearance after the juice of the plant has undergone a process of fermentation. The lichens employed in the preparation of archil and litmus are colorless, or at most light brown, but by steeping them in liquids containing ammonia and lime, a coloring matter of an intense red is gradually generated, which remains dissolved in the alkaline liquid. Other phenomena of a similar nature might be mentioned, as, for instance, the formation of the so-called Tyrian purple from the juice of a shell-fish, and now ones are from time to time being discovered. In order to explain these phenomena, various hypotheses have been resorted to. It was supposed, for instance, that the indigofere contained white or reduced indigo, and hence were devoid of color, and that the process of preparing indigo-blue consisted simply in oxidizing the white indigo, which was for this reason denominated indigogen by some chemists. The same assumption was made in regard to other coloring matters, all of which were supposed to exist originally in a deoxidized and colorless state. In regard to indigo, however, the hypothesis is disproved at once by the fact, that reduced indigo is only soluble in alkaline liquids, and that the juice of the indigo-bearing plants is always acid. In regard to the other coloring matters it seems also to be quite untenable. The first person to throw some light on this obscure department of organic chemistry was Robiquet. This distinguished chemist succeeded in obtaining from lichens in their colorless state a beautifully crystallized, colorless substance soluble in water, having a sweet taste, and consisting of carbon, hydrogen, and oxygen. This substance he denominated oricne. By the combined action of ammonia and oxygen, he found it to be converted into a red coloring matter, containing nitrogen, and insoluble in water, which was in fact identical with the coloring matter of archil. This beautiful discovery furnished chemists with a simple explanation for the curious phenomena observed in the formation of this and other coloring matters, and it was soon followed by others. Hoeren and Kane obtained from various lichens other colorless substances of similar properties, and it was shown by Schmeck that oricne is not even the first link in the chain, but is itself formed from another body, lecanorine, which, by the action of alkalis, yields oricne and carboxyl acid, just as sugar by fermentation gives alcohol and carboxyl acid. In like manner, it was discovered by Erdmann that the coloring matter of logwood is formed by the simultaneous action of oxygen and alkalis from a crystallized colorless substance, hematozylene, which is the original substance existing in the wood of the tree, and is like the others, not itself, strictly speaking, a coloring matter, but a substance which gives rise to the formation of one.

There is, however, another class of phenomena connected with the formation of coloring matters, entirely different from that just referred to. It was discovered by Robiquet, that if the brown juice of the madder be treated with sulphuric acid, and the acid be afterwards completely removed, the madder is found to have acquired a much greater tinctorial power.
than before. This fact was explained by some chemists by supposing that the sulphuric acid had combined with or destroyed some substance or substances contained in the madder, which had previously hindered the coloring matter from exerting its full power in dyeing, such as lime, sugar, woody fibers, &c. By others it was suspected that an actual formation of coloring matter took place during the process, and this suspicion has been verified by recent researches. Schunck succeeded in preparing from madder a substance resembling gum, very soluble in water, amorphous, and having a very bitter taste, like madder itself, and to which he gave the name of rubian. This substance, though not colorless, is incapable of combining with mordants, like most coloring matters. When, however, it is acted on by strong acids, such as sulphuric or nitric acid, it is completely decomposed, and gives rise to a number of products, the most important of which is alizarine, one of the coloring matters of madder itself. Among the other products are a yellow crystallized coloring matter, rubianine, two amorphous red coloring matters resembling resins, rubiretine and veraniline, and lastly, grape sugar. When subjected to fermentation, the same products are formed, with the exception of rubianine, which is replaced by a yellow coloring matter of similar properties. This process of decomposition evidently belongs to that numerous class called by some chemists "catalytic," in which the decomposing agent does not act, as far as we know, in virtue of its chemical affinities. It is evident, then, that when madder is acted on by sulphuric acid, an actual formation of coloring matter takes place, and it is even probable that the whole of the coloring matter found in madder in its usual state was originally formed from rubian, by a process of slow fermentation, the portion of the latter still remaining undecomposed being that which is acted on when acids are applied to madder. From the Isatis tinctoria, or common woad plant, Schunck, in like manner, extracted an amorphous substance, easily soluble in water, called by him indicen, and which, by the action of strong acids, is decomposed into indigo-blue, indigo-red, sugar, and other products, among which are also several resinosous coloring matters. Looking at them from this point of view, coloring matters may be divided into two classes, viz., first, such as are formed from other substances, not themselves coloring matters, by the action of oxygen and alkalies; and, secondly, such as are formed from other substances by means either of ferments or strong acids, without the intervention of oxygen. To the first class belong the coloring matters of archil, litmus, and logwood; they yield comparatively fugitive dyes, and are usually decomposed by allowing the very process to which they owe their formation to continue. To the second class belong indigo-blue, indigo-red, and alizarine, bodies which show a remarkable degree of stability for organic compounds. More extended research will probably show that many other coloring matters are formed either in one manner or the other, which will probably afford us the means of arriving at a rational mode of classifying these bodies, and of distinguishing them as a class from others.—Y. S.

**COlZA.** Colza oil is now extensively used for burning in lamps and for lubricating machinery. The Carcel, Modemtor, and other lamps, are contrived to give a continuous supply of oil to the wick, and by a rapid draught of air brilliant combustion of the oil is maintained without smoke.

In the lighthouses of France and England it has been employed with satisfaction, so as to replace the use of sperm oil; the prevalence has been given on the grounds of greater brilliancy, a steadier flame, the wick being less charred, and the advantage of economy in price.

The Corporation of the Trinity House and the late Mr. Hume took great interest in the question of the relative merits of colza, rape, and seed oils, as compared with sperm oil, and in 1845 referred the investigation of the power and qualities of the light from this description of oil, to Professor Faraday. He reported "that he was much struck with the steadiness of the flame, burning 12 or 14 hours without being touched;" "taking above 100 experiments, the light came out as one-and-a-half for the seed oil to one of the sperm; the quantity of oil being used in the same proportion;" and he concludes by stating his "confidence in the results."

The advantages then were, less trouble, for the lamps with sperm had to be retrimmed, and the same lamp with seed oil gave more light, and the cost then was as 6s. 9d. per gallon seed oil, against 6s. 4d. imperial gallon of sperm. Those interested should consult returns, ordered by the House of Commons,—"Lighthouses, on the motion of Mr. Hume, on the Substitution of Rape Seed Oil for Sperm Oil, and the Saving amount thereof." 17th Feb., 1857; No. 75; 18th March, 1857, 176 and 176 1°"

In the Supplementary Returns laid before the House of Commons by the Commissioners of the Northern Lights, there is the following report of Alan Stevenson, Esq., their Engineer:

"In the last annual report on the state of the lighthouses, I directed the attention of the Board to the propriety of making trial, at several stations, of the patent colza or rape seed oil, as prepared by Messrs. Briggs and Garford, of Bishopsgate street. These trials have now been made during the months of January and February, at three catoptric and
three dioptric lights, and the results have from time to time been made known to me by the light-keepers, according to instructions issued to them, as occasion seemed to require. The substantial agreement of all the reports as to the qualities of the oil renders it needless to enter into any details as to the slight varying circumstances of each case; and I have therefore great satisfaction in briefly stating, as follows, the very favorable conclusion at which I have arrived:

1. The culzà oil possesses the advantage of remaining fluid at temperatures which thicken the spermaceti oil.

2. The culzà oil burns both in the Fresnel lamp and the single argand burner, with a thick wick, during seventeen hours, without requiring any coaling of the wick, or any adjustment of the damper; and the flame seems to be more steady and free from flickering than that from spermaceti oil.

3. There seems (most probably owing to the greater steadiness of the flame) to be less breakage of glass chimney with the culzà than with the spermaceti oil.

The above firm, who from thirty years' experience in the trade were enabled to induce the Trinity Corporation to give this oil a fair and extended trial, state, that "for manufacturing purposes it is equally useful; it is admitted by practical men to be the best known oil for machinery—equal to Gallipoli; and technically it possesses more 'body,' though perfectly free from gummy matter." On this point, the following letter has due weight:

"Admiralty, 9th December, 1845.—Messrs. Briggs and Garford:—Referring to your letter of the 1st of August last, I have to acquaint you, in pursuance of the directions of the Lords Commissioners of the Admiralty, that the officers of Woolwich yard have tried your vegetable oil, and find it to be equal to the best Gallipoli.

"It is very hardy; and while sperna, Gallipoli, nut, or tord oils are rendered useless by the slightest exposure to frost, the patent oil will, with ordinary care, retain its brilliancy: this has been acknowledged as a very important quality to railway and steamboat companies."

It should be here stated, that the terms rape oils, seed oils, colza, or culzà, are all now blended together; and, however much this may be regretted, yet it does not seem easy to keep distinctness in the general usages of oil, for the customs returns class all under one head—rape oil.

A number of British and colonial seed-bearing plants appear to be now employed for the sake of their oils, although, on account of the mucilaginous matter contained in many of the oils, they are far inferior to the colza, which they are employed to adulterate.—

T. J. P.

COMB. The name of an instrument which is employed to disentangle, and lay parallel and smooth the hairs of man, horses, and other animals. They are made of thin plates, either plain or curved, of wood, horn, tortoise-shell, ivory, bone, or metal, cut upon one or both sides or edges with a series of somewhat long teeth, not far apart.

Two saws mounted on the same spindle are used in cutting the teeth of combs, which may be considered as a species of grooving process; one saw is in this case larger in diameter than the other, and cuts one tooth to its full depth, whilst the smaller saw, separated by a washer as thick as the required teeth, cuts the succeeding tooth part-way down.

A few years back, Messrs. Pow and Lyne invented an ingenious machine for sawing boxwood or ivory combs. The plate of ivory or box-wood is fixed in a clamp suspended on two pivots parallel with the saw spindle, which has only one saw. By the revolution of the handle, a cam first depresses the ivory on the revolving saw, cuts one notch, and quickly misses it again; the handle, in completing its circuit, shifts the slide that carries the suspended clamp to the right, by means of a screw and ratchet movement. The teeth are cut with great exactness, and as quickly as the handle can be turned; they vary from about thirty to eighty teeth in one inch, and such is the delicacy of some of the saws, that even 100 teeth may be cut in one inch of ivory. The saw runs through a cleft in a small piece of ivory, fixed vertically or radially to the saw, to act as the ordinary stops, and prevent its flexure or displacement sideways. Two combs are usually laid one over the other and cut at once; occasionally the machine has two saws, and cuts four combs at once.

In the manufacture of tortoise-shell combs, very much ingenuity is displayed in soldering the back of a large comb to that piece which is formed into teeth. The two parts are filed to correspond; they are surrounded by pieces of linen, and inserted between metal moulds, connected at their extremities by metal screws and nuts; the interval between the halves of the mould being occasionally curved to the sweep required in the comb; sometimes also the outer faces of the mould are curved to the particular form of those combs in which the back is curled round, so as to form an angle with the teeth. Thus arranged it is placed in boiling water. The joints, when properly made, cannot be detected, either by the want of transparency or polish. Much skill is employed in turning to economical account the flexibility of tortoise-shell in its heated state: for example, the teeth of the larger descriptions of comb are parted, or cut one out of the other with a thin frame saw; then the shell, equal in size to two combs with their teeth interlaced, is bent like an arch in the
COMBINING NUMBERS—CHEMICAL COMBINATION.

direction of the length of the teeth. The shell is then flattened, the points are separated with a narrow chisel or pricker, and the two combs are finished, whilst flat, with coarse single-cut files, and triangular scrapers; and lastly, they are warmed, and held on the knee over a wooden mould by means of a strap passed round the foot, in the manner a shoemaker fixes a shoe-last. Smaller combs of horn and tortoise-shell are parted whilst flat, by an ingenious machine with two chisel-formed cutters, placed obliquely, so that every cut produces one tooth, the repetition of which completes the formation of the comb.

Mr. Rogers's comb-cutting machine is described in the Transactions of the Society of Arts, vol. xlix., part 2, page 150. It has been since remodelled and improved by Mr. Kelly. This is an example of slender chisel-like punches. The punch or chisel is in two parts, slightly inclined and curved at the ends to agree in form with the outline of one tooth of the comb, the cutter is attached to the end of a jointed arm, moved up and down by a crank, so as to penetrate almost through the material, and the menat portion is so very thin that it splits through at each stroke, and leaves the two combs detached.

The comb-maker's double saw is called a "stakula," and has two blades contrived so as to give with great facility and exactness the intervals between the teeth of combs, from the coarsest to those having from forty to forty-five teeth to the inch. The page-saw or page-vid is used to make the teeth square and of one depth. The saw is frequently made with a loose back, like that of ordinary back-saws, but much wider, so that for teeth \( \frac{3}{8} \) to \( \frac{3}{4} \) inch long, it may shield all the blade except \( \frac{3}{8} \) to \( \frac{3}{4} \) inch of its width respectively, and the saw is applied until the back prevents its further progress. Sometimes the blade has teeth on both edges, and is fixed between two parallel slips of steel connected beyond the ends of the saw blade by two small thumb-screws. After the teeth of combs are cut, they are smoothed and polished with files, and by rubbing them with pumice stone and tripoli.

COMBINATION OF ELEMENTS.—In the preparation of every chemical compound, the elements, to which it is composed, are united; these united elements are termed a compound. A compound consists of elements, always in the same proportion. The proportion of the elements forming a compound is not altered by the quantity in which such a compound is prepared, but is the same in all cases. In a compound the elements are combined so as to form a new or different substance. The compound, instead of being the mere sum of its constituents, is entirely different from them. In the combination of elements, all the elements are always united, as in the case of water, which consists of two elements, hydrogen and oxygen.

COMBINATION OF NUMBERS AND CHEMICAL COMBINATION.—Constancy of composition is one of the most essential characters of chemical compounds; by which is meant that any particular body, under whatever circumstances it may have been produced, consists invariably of the same elements in identically the same proportion; the converse of this is not, however, necessarily true, that the same elements in the same proportion always produce the same body.

But not only is there a fixes in the proportion of the constituents of a compound, but also, if any one of the elements be taken, it is found to unite with the other elements in a proportion which is either invariable, or changes only by some very simple multiple.

The numbers expressing the combining proportions of the elements are always relative. In England it is usual to take hydrogen as the starting point, and to call that number the combining number of any other element which expresses the proportion in which it unites with one part by weight of hydrogen; and these numbers are now becoming adopted on the Continent, although in France the combining numbers are still referred to oxygen, which is taken as 100. It is obvious that, whichever system is used, the numbers have the same value relatively to each other.

These combining numbers would have but little value if they expressed nothing more than the proportion in which the elements combine with that body arbitrarily fixed as the standard; but they also represent the proportions in which they unite among themselves in the event of union taking place. Thus, not only do 8 parts of oxygen unite with one of hydrogen, but also 8 parts of oxygen unite with 39 of potassium, 25 of sodium, 100 of mercury, 108 of silver, &c. It is in virtue of this law that the combining proportions of many of the elements have been ascertained. Some of them do not combine with hydrogen at all, and in such cases the quantity which unites with 8 parts of oxygen, or 16 of sulphur, &c., has to be ascertained. H. M. W.

COMBUSTION. (Eng. and Fr.; Verbrennung, Germ.) The phenomena of the development of light and heat from any body, as from charcoal combining with the oxygen of the air, from phosphorus combining with iodine, and from some of the metals combining with chlorine. Combustion may be excited with very various degrees of energy. We have a low combustion often established in masses of vegetable matter; as in hay-stacks, or in heaps of damp sawdust. In these cases, the changes going on are the same in character, only varying in degree, as those presented by an ordinary fire, or by a burning taper,—oxygen is combining with carbon to form carbonic acid. The heat thus produced, (the process has been termed by Liebig Eremitica, increasing in force, gives rise eventually to visible combustion.

COOLING FLUIDS. See Refrigeration of Worts.

COPPER.—Mechanical Preparation of the Copper Ore in Cornwall.—The ore receives a first sorting, the object of which is to separate all the pieces larger than a nutshell; after which the whole is sorted into lots, according to their relative richness. The fragments of poor ore are sometimes pounded in stamps, so that the metallic portions may be separated by washing. The rich ore is either broken into small bits, with a flat beater, or by means of a crushing-mill. The ore to be broken by the bucking-iron is placed upon plates of cast-iron,
COPPER.

each about 16 inches square and 1½ inches thick. These plates are set towards the edge of a small mound about a yard high, constructed with dry stones rammed with earth. The upper surface of this mound is a little inclined from behind forwards. The work is performed by women, each furnished with a bucking-iron; the ore is placed in front of them beyond the plates; they break it, and strew it at their feet, whence it is removed and dispersed as may be subsequently required.

The crushing-mill has of late years been brought to a great degree of perfection, and is almost universally made use of for pulverizing certain descriptions of ore. For a description of this apparatus, see GRINDING AND CRUSHING MACHINERY.

Stamping-mills are less frequently employed than crushers for the reduction of copper ores. At the Devon Great Consols Mines, the concentration of the crushed copper ores is effected in the following manner:—From the crushing-mill the stuff is carried by a stream of water into a series of revolving separating sluices, where it is divided into fragments of 1/16 inch, 1/32 inch, and 1/64 inch diameter, besides the coarser particles which escape at the lower end of the sluices. The slimes flow over a small water-wheel called a separator, in the buckets of which the coarser portions settle, and are from thence washed out by means of jets of water into a round baffle, whilst the finer particles are retained in suspension, and are carried off into a series of slime-pits, where they are allowed to settle.

The work produced by the round baffle is of three sorts; that nearest the circumference is the least charged with iron pyrites, or any other heavy material, but still contains a certain portion of ore; this is again buddled, when a portion of its tail is thrown away, and after submitting the remainder to a budding operation, and separating the waste, it is jigged in a fine sieve, and rendered merchantable.

The other portions of the first baffle are rebuddled, and after separating the waste, the ore materials are introduced into sizing esterns, from which the finer particles are made to flow over into a baffle, from whence a considerable portion goes directly to market. That which requires further manipulation is again buddled until thoroughly cleansed. The coarser portions of the stuff introduced into the sizing esterns pass downward with a current of water into the tyne, and after repeated projections against the stream, the orey matter is separated, leaving a residue of muddle in a nearly pure state.

The stuff falling from the lower extremities of the separating sluices is received into bins and subsequently cleaned, each of the three sizes is jigged, and in proportion as the worthless matters are separated, they are scraped off and removed. Those portions of the stuff that require further treatment are taken from the sluices, washed down from behind the baffles, and treated by tyne, until all the valuable portions have been extracted.

In this way, a baffle of stuff that originally contained but 1½ per cent. of copper, is so concentrated as to afford a metallic yield of 10 per cent., whilst, by means of sizing-slues, dressing-wheels, jiggling-machines, and round-buddles, &c., from 40 to 50 tons of stuff are elaborated per day of 9 hours, at a cost of 1½s. per ton of dressed ore.

Captain Richards, the agent of these mines, has also introduced considerable improvements in the slime-dressing department. The proper sizing of slime is as necessary as in the case of rougher work, and in order to effect this, he has arranged a slime-pit, which answers this purpose exceedingly well. This pit has the form of an inverted cone, and receives the slimes from the slime-separator, in an equally divided stream. The surface of this apparatus being perfectly level, and the water passing through it at a very slow rate, all the valuable matters are deposited at the bottom. If slime be valuable in the mass, it can evidently be more economically treated by a direct subdivision into fine and coarser work; since a stream of water, acting on a mixture of this kind, will necessarily carry off an undue proportion of the former in freeing the latter from the waste with which it is contaminated.

The ordinary slime-pit is of a rectangular form, with vertical sides, and flat bottom. The water enters it at one of the ends by a narrow channel, and leaves it at the other. A strong central current is thus produced through the pit, which not only carries with it a portion of valuable slime, but also produces eddies and creates currents towards the edges of the pit, and thus retains matters which should have been rejected. The slime-pits at Devon Consols are connected with sets of Brunton's machines, which are thus kept regularly supplied by means of a launder from the apex of the inverted cone, through which the flow is regulated by means of a plug-valve and screw.

A wagon estern is placed under each frame for receiving the work, which is removed when necessary, and placed in a packing-kieve. This is packed by machinery, set in motion by a small water-wheel. The waste resulting from this operation is either entirely rejected, or partially reworked on Brunton's machines, whilst the orey matters contained in the kieve are removed by a wagon to the orehouse, where they are discharged.}

Napier's Process for Smelting Copper Ores.—As the copper ores of this country often contain small portions of other metals, such as tin, antimony, arsenic, &c., which are found to deteriorate the copper, Mr. Napier's process has in view to remove these metals, and at the same time to shorten the operations of the melting process.
The first two operations, that of calcining and fusing the ore, are the same as the ordinary process; but the product of this last fusion—viz., the coarse metal—is again fused with a little sulphate of soda and coal mixed. And whenever this becomes solid, after tapping the furnace, it is thrown into a pit of water, where it immediately falls into an impalpable powder; the water boils, and then contains caustic soda and sulphide of sodium, dissolving from the powder those metals that deteriorate the copper, the lye is let off, and the powder washed by allowing water to run through it. The powder is then put into a calcining furnace, and calcined until all sulphur is driven off, which is easily done from the finely divided state of the mass. This calcined powder is now removed to a fusing furnace, and mixed with ores containing no sulphur, such as carbonates and oxides, and a little ground coal, and the whole fused; the result of this fusion is metallic copper and sharp slag—that is, a scoria containing much protoxide of iron, which is used as a flux in the first fusion of the calcined ore, so that any small trace of copper which the slag may contain is thus recovered.

The copper got from this fusion is refined in the ordinary way, and is very pure.

When the copper ores contain tin to the extent of from \(\frac{1}{2}\) per cent. to 2 per cent., which many of them are found to do, Mr. Napier proposes to extract this tin, and make it valuable by a process which has also been the subject of a patent. The ore is first ground and calcined, till the amount of sulphur is a little under one-fourth of the copper present, the ore is then fused with a little coal. The result of this fusion, besides the scoria, is a regulus composed of sulphur, copper, and iron, and under this is a coarse alloy of copper, tin, and iron, called white metal. This alloy is ground fine, and calcined to oxidize the metals, which are then fused in an iron pot with caustic soda, which combines with the tin and leaves the copper. The oxide of copper is now fused with the regulus. The stannate of soda is dissolved in water, and the tin precipitated by slaked lime, which is dried and fused with carbonaceous matters and a little sand, and metallic tin obtained; the caustic soda solution is evaporated to dryness and used over again. This process is well adapted for very poor copper ores that are mixed with tin, or poor tin ores mixed with copper.

The Process of Extracting Copper from Ores, at the Mines in the Riodinio District, Province of Huelva, Spain, by what is termed "Artificial Concretion.

(Translated from the newspaper "Minero Español" for January 23, 1858.)

This method, which was first applied here by Don Felipe Prieto, a mine proprietor of Seville, in the year 1845, is the only one employed in the present day in the copper mines of that district.

The operation begins with the calcination of the ores, previously reduced to small pieces; piles or heaps of these ores (sometimes in the form of cones) are made on beds of stubble fire-wood of about a yard thick; each pile is made up with from 400 to 500 tons of mineral, and allowed to burn for six months; the smoke destroying all vegetation within its reach.

The ores, after being thus burnt or calcined, are thrown into wooden troughs let into the ground, about 6 yards long, 4 wide, and 1 1/2 deep, called "dissolvers." In each of these troughs, or cisterns, are placed about twelve tons of calcined ore, and the trough is then filled with water; which water is, after remaining in contact with the ores for forty-eight hours, drained off into a similar trough placed at a lower level, and called a "depositor." The ores remaining in the dissolver are covered by a second quantity of water, left on this time, for three days; and the process repeated four times successively, the water being always drained off into the same depositor.

From the depositors the water flows on to another set of troughs called "pilones," into which is placed a quantity of pig iron, broken into pieces of about the size of bricks, and piled loosely together that the vitriol in the water may better act on its whole surface. Each of these troughs (pilones) will hold from 12 to 18 tons of pig iron, (wrought iron answers the purpose as well, but it is much more expensive); and, as experience has demonstrated that a slow continuous movement in the water hastens the process, a man is employed for the purpose of agitating it, until all the copper suspended in the vitriol water is deposited, which, in summer, is effected in about 2 days, and in from 3 to 5 days in winter. After the water has been renewed four or five times, and the agitation process repeated, the scales of copper deposited on the iron, as well as that in the form of coarse grains of sand found in the bottom of the trough, are collected together, washed, and melted; when it is found to produce from 65 to 70 per cent. of pure copper.

From the remains of the first washings of the above copper scales, &, another quality is obtained, worth about 50 per cent. for copper, which is mixed with the after washings, yielding about 10 per cent. of copper, and passed on to the smelting furnace.

This method is very defective. Minerals containing 5 per cent. of copper, treated by this system of reduction, will scarcely give a produce of 2 per cent. of that metal. It is, however, the only known method that can be profitably employed in the Riodinio district.
COPPER.

[Note by the Translator.—The average produce of the copper ores of the Riotinto district by this process is under 1/2 per cent. The following quantities, put into English measure, are taken from the returns of the Government mines at Riotinto, published in the "Revista Minera":—]

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of Ores mined.</th>
<th>Quantity of Copper produced.</th>
<th>Produce per Cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1854</td>
<td>-</td>
<td>38,915</td>
<td>1.85</td>
</tr>
<tr>
<td>1855</td>
<td>-</td>
<td>37,123</td>
<td>2.24</td>
</tr>
<tr>
<td>1856</td>
<td>-</td>
<td>37,866</td>
<td>1.98</td>
</tr>
<tr>
<td>Average</td>
<td>-</td>
<td>37,908</td>
<td>2.0 of 4 years</td>
</tr>
</tbody>
</table>

The produce of some of the mines of the district is under 1 per cent. A quantity of the richest of the copper ores produced by the mines in the Riotinto district in the year 1857 has been shipped from Huelva, a port near Seville, for Newcastle, in England; and it has been reported here that the value of the sulphur saved in the process of reduction has contributed largely towards paying the smelting expenses.—S. H.]

The Process of Extracting Copper from the Water that Drains out of the Mine at Riotinto, called the "System of Natural Cementation," (Precipitation.)

(Translated from the "Minero Español" for January 26, 1858.)

The mine worked by the Spanish Government at Riotinto is formed in a mass of iron pyrites containing copper; and its immense labyrinth of excavations are known to extend over a length of 500 yards and a width of 100 yards, (and probably to a much greater extent;) the earliest of which workings must date back to very remote times; for in the different excavations are still to be found the impressions of hands, evidently guided by the science of the ancients, middle ages, and of more modern times.

The sixth, or lowest level in the mine, where all the operations of the present day are carried on is 80 yards deep, (from the top of the hill in which the lode is found,) and it is from this level that the mine is (naturally) drained by an adit. From the roof, at the extreme end of a gallery at this level, flows, from an unknown source, a stream of water rich in copper, which, together with the drainage from other points of the mine, is directed through a channel to the adit "San Roque," that empties its waters at the foot of the hill, where the copper is extracted.

An able engineer has thus explained the phenomena of "natural cementation":—"The natural ventilation through the open excavations of this mine, combined with the humidity of the ground, produces a natural decomposition of the materials composing the lode or vein, and thereby forming sulphates of iron and copper, which the water is continually dissolving and carrying off, thus forming the substance of this 'natural cementation'."

This said adit "San Roque," which empties its waters on the south side of the hill, has placed in it two wooden launders, or channels, about 12 inches wide and 15 inches deep, and (in the year 1855) 400 yards long; in the bottom of these launders are placed pieces of pig iron, and to this iron adhere the particles of copper which the slowly flowing water contained in solution. In ten days the iron becomes coated with copper, so pure as to be worth 80 per cent. for fine copper, and so strongly formed in scales as to resist to a certain extent the action of a file, and give a strong metallic sound on being struck with a hammer. At the expiration of ten days or earlier, the scales of copper so formed on the iron are removed, that the surface of the iron may be again exposed to the action of the mineral water; and the process repeated to the entire extinction of the iron. The copper thus obtained passes at once to the refining furnace.

Since 1853 it has been discovered that the water escaping from the launders in the adit, 400 yards long, still contained copper, and they have been lengthened to nearly 1,000 yards with good effect.

[Note by the Translator.—The "Revista Minera," (a mining review) published by the engineers of the Government School of Mines, in Madrid, gives returns of the Government mines at Riotinto for the year 1856; wherein it is stated that the quantity of copper taken out of this mineral water, by "natural cementation," amounted, for the year, to 206½ tons.

—S. H.]

* But this average of 2 per cent. for the 4 years contains and includes the copper produced from the water which drains out of the mine, and which copper, for the year 1856, amounted to 206½ tons; deducting this quantity from the return, 749 tons, for that year, and the produce would be only 146 per cent. for the ore.
The following processes for the humid treatment of copper ores are described by Messrs. Phillips and Darlington:—*

_Linz Copper Process._ At Linz on the Rhine, and some other localities in Germany, the poorer sulphides of copper, containing from 2 to 5 per cent. of that metal, are treated by the following process:—

"The ores coming directly from the mine, and without any preliminary dressing, are first roasted in a double-soled furnace, and then taken to a series of tanks sunk in the ground, and lined with basalt. These tanks are also provided with a double bottom, likewise formed of basalt, so arranged as to make a sort of permeable diaphragm, and on this is placed the roasted ore, taking care that the coarser fragments are charged first, whilst the finer particles are laid upon them. The cavity thus formed between the bottom of the tank and the diaphragm, or false bottom, is connected, by means of proper flues, with a series of oblong retorts, through each of which a current of air is made to pass from a ventilator, or a pair of large bellows, set in motion by steam or water power.

"In order to use this apparatus, a quantity of ore is roasted in the reverberatory furnace, and subsequently placed in the tanks, taking care that the first layer shall be in a coarser state of division than those which succeed it.

"The retorts—which are formed of fire tiles, and about 6 inches in height by 1 foot in width and 6 feet in length—are now brought to a red heat, charged with blende, and the blast applied.

"The sulphurous acid thus formed is forced by the draught through the flues, where it becomes mixed with nitrous fumes, obtained from a mixture of nitrate of soda and sulphuric acid, and ultimately passes into the chambers beneath the diaphragm on which are laid the roasted ores, which must be previously dampened by the addition of a little water, of which a small quantity is also placed in the bottoms of the tanks. The sulphuric acid thus generated attacks the oxide of copper formed during the preliminary roasting, giving rise to the production of sulphate of copper, which percolates through the basaltic diaphragm into the reservoir beneath.

"The liquors which thus accumulate are from time to time distributed over the surface of the ore, and the operation repeated until the greater portion of the copper has been extracted, when, by shifting the damper, the gases are conducted into another tank similarly arranged. The liquors from the first basin are now pumped into the second, and the operation continued until the ores which it contains have ceased to be acted on by the acid. When sufficiently saturated, the liquors are drawn off into convenient troughs, and the copper precipitated by means of scrap iron. The sulphate of iron thus formed is subsequently crystallized out, and packed into casks for sale.

"On removing the attacked ores from the tank, the finer or upper portions are thrown away as entirely exhausted, nearly the whole of the copper having been removed from them, whilst the coarser fragments are crushed and re-roasted, and finally form the upper stratum in a subsequent operation.

"It has been found that, by operating in this way, ores yielding only 1 per cent. of copper may be treated with considerable advantage, since the sulphate of iron produced, and the increased value of the roasted blende, are alone sufficient to cover the expenses of the operation.

"By this process, 5 cwt. of coal are said to be required to roast one ton of ore, whilst the same quantity of blende is roasted by an expenditure of 4 cwt. of fuel."

_Treatment of Copper Ores by Hydrochloric Acid._ At a short distance from the village of Twista, in the Walbeck, several considerable bands of sandstone, more or less impregnated with green carbonate of copper, have been long known to exist. Although varying considerably in its produce, this ore, on the average, yields 2 per cent. of copper, and was formerly raised and smelted in large quantities; but this method of treatment not having apparently produced satisfactory results, the operations were ultimately abandoned.

"The insoluble nature of the granular quartzitic gangue with which the copper is associated, suggested, some two years since, to Mr. Rhodius, of the Linz Metallurgie Works, the possibility of treating these ores by means of hydrochloric acid, and a large establishment for this purpose has ultimately been the result.

"These works consist of a crushing mill, for the reduction of the cuprous sandstone to a small size, 10 dissolving tanks, and a considerable number of tanks and reservoirs for the reception of the copper liquors and the precipitation of the metal by means of scrap iron. Each of the 16 dissolving tanks is 15 feet in diameter, and 4 feet in depth, and furnished with a large wooden revolving agitator, set in motion by a run of overhead shafting in connection with a powerful water-wheel. This arrangement admits of the daily treatment of 20 tons of ore, and the consequent production of from 7 to 8 cwts. of copper. Each operation is completed in 24 hours, the liquor being removed from the tanks to the precipitating trough by the aid of wooden pumps. The ore is stopped and brought into the works at 4s. per ton.

* Records of Mining and Metallurgy, p. 182.
COPPER.

The acid employed at Twista is obtained from the alkali works in the neighborhood of Frankfort, contains 16 per cent. of real acid, and costs, delivered at the works, 2s. per 100 lbs. Each ton of sandstone treated requires 400 lbs. of acid, which is diluted with water down to 10 per cent. before being added to the ore. Every ton of copper precipitated requires 1½ tons of scrap iron at £4 8s. per ton.

These works yielded during the last year 120 tons of metallic copper, and afforded a net profit of nearly 50 per cent. The residues from the washing vats, run off after the operation, contain but ½ per cent. of copper.

It is probable that this extremely simple process of treating the poorer carbonates and oxides of copper may be practicable in many other localities; but in order to be enabled to do so with advantage, it is necessary that the ore should be obtainable in large quantities at a cheap rate, and that it should contain but little lime or any other substance than the ores of copper soluble in dilute hydrochloric acid. It is also essential that the mine should be in the vicinity of alkali works, in order that a supply of acid may be obtained at a cheap rate, and also that scrap iron be procurable in sufficient quantities and at a moderate price.

**Assay of Copper Ores.**

The ores of this metal are exceeding numerous, but may be comprehended under three classes:

The first class includes those ores which contain, with the exception of iron, no metal except copper, and are free from arsenic and sulphur.

The second class comprehends those ores which contain no other metal than copper and iron, but in which a greater or less proportion of sulphur is present.

The third class consists of such ores as contain other metals in addition to iron and copper, together with sulphur or arsenic, or both.

The apparatus best adapted for the assay of copper ores is a wind furnace, about 16 inches in depth, and of which the width may be 8 inches, and the length 10 inches. This must be supplied with good hard coke, broken into fragments of about the size of a small orange.

**Ores of the First Class.**—When these are moderately rich, their assay offers no difficulty, and usually affords satisfactory results. The sample, after being ground in a mortar and well mixed to insure uniformity of composition, is intimately blended with three times its weight of black flux. The whole is now introduced into a crucible, of which it should not occupy above one-third the capacity, in order to avoid loss from the subsequent swelling of the pasty mass when heated; and on the top is uniformly spread a thin layer of carbonate of soda.

The crucible and its contents are now placed in the furnace, previously heated to redness, and the pot is allowed to remain uncovered until the ore and flux have become reduced to a state of tranquil fusion. This will take place in the course of about a quarter of an hour, and the crucible is then closed by a cover, and the damper opened so as to subject the assy, during another quarter of an hour, to the highest temperature of the furnace. The crucible is then removed from the fire, and the metallic button obtained, either by rapid pouring into a mould, or by allowing the pot to cool, and then breaking it.

The metallic "prill" thus obtained, may subsequently, if necessary, be refined according to the Cornish process, to be hereafter described.

**Ores of the Second Class.**—The most common ores of this class are copper pyrites and other sulphides.

**Fusion for Regulus.**—This process consists in fusing the ores with fluxes capable of removing a portion of its sulphur, and eliminating siliceous and earthy impurities. These conditions are well fulfilled by a mixture of nitre and borax, since, with a proper proportion of these reagents, all the ores belonging to this class are fused with the formation of a vitreous slag and a well-formed button of regulus. When the contents of the crucible have been completely fused, they must be rapidly poured into an iron or bell-metal mould of a conical form.

The separation of the regulus from the scorina must be carefully effected by the use of a small chisel-edged hammer, a sheet of paper being placed under the button to prevent loss.

**Roasting.**—To obtain the pure metal from the sulphides of copper, it is necessary that the sulphur, &c., should be removed by roasting before reducing the copper present to the metallic state.

When rich ores, producing from 20 to 25 per cent. of metallic copper, are operated on, the roasting and subsequent reduction may be made directly on the mineral. When, however, poor ores, such as those of Cornwall, containing from 6 to 10 per cent., are to be treated, it is far better to commence by obtaining a button of regulus as above.

The calcination of the rich ore or regulus is conducted in the same crucible in which the subsequent fusion with reducing agents is to take place; and at the commencement of
COPPER.

the operation care must be taken not to cause the agglutination of the ore, or pulverized button, by the application of too high a temperature. In order to succeed in effecting this object, the ore or regulus must be first finely powdered in an iron mortar, and then put into an earthen crucible, which is to be placed in a sloping position on the ignited coke with which the furnace is filled, the draught at the same time being partially cut off by the damper.

A moderate heat is thus obtained, and the mixture is continually stirred by means of a slight iron rod, so that each particle may in its turn be exposed to the oxidizing influences of the atmosphere. When a large portion of the sulphur, &c., has been driven off, the contents of the crucible become less fusible, and may without inconvenience be heated to redness. At this stage, it is often found advantageous to heat the partially roasted mass to full redness, since by this means the sulphides and sulphiates become reduced to the state of oxides by their mutual reaction on each other.

As soon as the smell of sulphur can no longer be observed, and the roasting process is consequently in an advanced state, the heat should for some minutes be increased to whiteness, in order to decompose the sulphiates, after which the crucible may be withdrawn and allowed to cool.

Reduction.—To obtain the copper from the roasted ore or matt, it may be mixed with one-fourth its weight of lime, from 10 to 20 per cent. (according to the produce of the ore) of finely powdered charcoal, from 1 to 1½ times its weight of soda ash or pearl ash, and a little borax. When this has been well mixed, it is placed in the crucible in which the roasting of the ore, or regulus, has been conducted, and covered with a thin stratum of fused borax.

In lieu of powdered charcoal, from 15 to 20 per cent. of crude tartar is sometimes employed.

The crucible is now placed in the fire and strongly heated for about a quarter of an hour, at the expiration of which time the bubbling of the assay will have ceased, and it must then be closed by an earthen cover, and for a short time heated nearly to whiteness.

The prill may be obtained either by rapidly pouring into a suitable mould or by allowing the pot to cool and then breaking it. If required, the resulting button may be refined by the Cornish method.

Ores of the Third Class.—Minerals belonging to this class must be treated like those of the second, excepting that the preliminary roasting should, from their greater fusibility, be conducted at a lower temperature. The button obtained from the calcined ore, or regulus, will in this case consist of an alloy of copper and other metals instead of, as in the former instances, being nearly pure copper.

If an ore contains lead, the roasting must at first be conducted with the greatest precaution, since it is extremely difficult so to moderate the heat as to cause at the same time the elimination of the arsenic and sulphur, and avoid the agglutination of the mass.

The assay of ores belonging to this class should in all cases be commenced by a fusion for matt.

The refining of the button obtained from such assays may be effected either by the Cornish method, or by the humid process, to be hereafter described.

Cornish Method of conducting an Assay.—A portion of the powdered and sifted ore is first burnt on a shovel, and examined as to its supposed richness and the amount of sulphur, arsenic, and other impurities it may contain. A little practice in this operation will enable the operator to judge with considerable accuracy of the quantity of nitre necessary in order to obtain a good regulus.

Two hundred grains of the mixed ore are now weighed out and carefully mixed with a flux consisting of nitre, borax, lime, and fluor-spar, and the fusion for matt or regulus is begun. The quantity of nitre used will of course vary with the amount of sulphur and arsenic present; but the other ingredients are commonly employed in the following proportions:—Borax, 5 dwts.; lime, 1½ laddlefuls; fluor spar, 1 laddleful. After being placed in the crucible, the whole is generally covered by a thin stratum of common salt. After remaining in the fire for about a quarter of an hour, the fusion will be found complete, and the contents of the pot may be poured into a suitable iron mould. The button or regulus is now examined, in order to determine whether a suitable proportion of nitre has been used. If the right quantity has been employed, the button, when broken, should present a granular fracture, and yield from 8 to 10 for 20° for copper, &c., from 40 to 50 per cent. However rank a sample may be, it should never be mixed with above 9 or 9½ dwts. of nitre; and if the amount of sulphur be small, 8 dwts. are often sufficient. The grey sulphiates, the red and black oxides, and carbonates, have sulphur added to them for the purpose of obtaining a regulus.

Highly sulphurized samples, requiring above 9½ dwts. of nitre, are sometimes treated in a different way.

* The ladle used for this purpose is three-quarters of an inch in diameter and half an inch in depth.
COPPER. 415

In this case the ores are first carefully roasted, and afterwards fused with about 5 dwts. of nitre, 9 dwts. of tartar, and 3 dwts. of borax.

The roasting of the regulus thus obtained is performed in a smaller crucible than that used in the fusion for matt. During the first quarter of an hour, a very low temperature is sufficient. The heat is then increased to full redness, and the assay allowed to remain on the fire for a further period of about 20 minutes. During the first 15 minutes it should be kept constantly stirred with a slender iron rod; but afterwards an occasional stirring will be found sufficient. When nearly the whole of the sulphur and arsenic has been expelled, the temperature must be raised nearly to whiteness during a few minutes, and the assay then withdrawn and allowed to cool. The fusion for copper is effected in the same crucible in which the roasting has been carried on.

The quantity of flux to be used for this purpose varies in accordance with the weight of the button of regulus obtained. A mixture of 2 dwts. of nitre, 7½ dwts. of tartar, and 1½ dwts. of borax, is sufficient for the reduction of a calcined regulus that, previous to roasting, weighed from 55 to 60 grains. In the case of a button weighing from 90 to 100 grains, 3½ dwts. of nitre, 9 dwts. of tartar, and 2 dwts. of borax, should be employed. These quantities are, however, seldom weighed, since a little practice renders it easy to guess, with a sufficient degree of accuracy, the necessary amounts.

The prill of copper thus obtained is seldom fine, and consequently requires purification.

A crucible is heated to redness in the furnace, the metallic button is taken from the mould and thrown into it, and some refining flux and salt are placed in a scoop for immediate use.* In a few minutes the fusion of the prill is effected. The crucible is now taken from the fire by a pair of tongs, the contents of the scoop introduced, and a gentle agitation given to it: an appearance similar to the brightening of silver on the cupel now takes place, and the crucible is returned to the fire for about four minutes.

The crucible is now removed, and its contents rapidly poured into a mould. The button thus obtained will consist of pure copper, and present a slight depression on its upper surface.

The slags from the reducing and refining operations are subsequently fused with a couple of spoonsfuls of crude tartar, and the prill thus obtained weighed with the larger button.

Inland Method of assaying Copper Ores.—In some localities, and particularly in the United States of America, the assay of copper ores is performed by the humid process. The whole of the ores belonging to the three different classes may be estimated in this way:

A weighed quantity of the pulverized ore is introduced into a long-necked flask of hard German glass, and slightly moistened with water. Nitric acid is now added, and the flask exposed to the heat of a sand bath. A little hydrochloric acid is subsequently introduced, and the attack continued until the residue, if any remains, appears to be free from all metallic stains.

The contents of the flask must be transferred to a porcelain evaporating dish, and evaporated to dryness, taking care, by means of frequent stirring, to prevent the mass from spiriting. The whole must now be removed from the sand bath and allowed to cool, a little hydrochloric acid subsequently added, and, afterwards, some distilled water. The contents of the basin must then be made to boil, and, whilst still hot, filtered into a beaker. A piece of bright wrought iron, about two inches in length, three-quarters of an inch in width, and a quarter of an inch in thickness, is now introduced, and the liquor gently heated on the sand bath until the whole of the copper has been thrown down. The liquor is now removed by means of a glass siphon, and the metallic copper freed from all adhering chlorides, by means of repeated washings with hot water, and then dried in a water bath, and weighed.

In case the mineral operated on should contain tin or antimony, very minute traces only of these metals will be found with the precipitated copper. When lead is present, it is best to add a few drops of sulphuric acid during the process of the attack; by this means the lead will be precipitated as sulphate of lead, and be removed by filtration. The results obtained by this process are somewhat higher than afforded by the fire assay.—J. A. P.

COPPER, NITRATE OF, prepared by dissolving copper in moderately strong nitric acid, and evaporating to crystallization. Its formula is CuO,NO₃. This salt is used to produce a fine green in fireworks.

COPPER, SULPHATE OF, called in commerce BLUE VITRIOL, BLUE STONE, BLUE COPPER. This salt is frequently prepared by roasting copper pyrites with free access of air.

It is also obtained by heating old copper with sulphur, by which a subsulphide of copper is

*The refining flux consists of two parts of nitre and one of white tartar fused together, and subsequently pounded.
COPYING.

produced; this is converted into sulphate, by roasting in contact with air. Large quantities of sulphate of copper are obtained in the process of silver refining. See Pyrites and Silver.

COPYING. A new and important quality of writing-inks was introduced by the indefatigable James Watt, in 1750, who in that year took out a patent for copying letters and other written documents by pressure. The modus operandi being to have mixed with the ink some saccharinic or gummy matter, which should prevent its entire absorption into the paper, and thus render the writing capable of having a copy taken from it when pressed against a damp sheet of common tissue paper. But although this process was very imperfect, the writing generally being much beamoured by the damping, and the copies, in many cases, only capable of being read with great difficulty, it was not for seventy-seven years after the invention of Watt that any improvement in such inks was attempted. The firm of Underwood and Burt patented a method of taking copies by the action of a chemically prepared paper, in a chemical ink, by which, not only are fair superior copies taken, and the original not at all damaged, but many copies may be taken at one time from a single document. Printed matter may also be copied at the same time, on the same beautiful principle. We give the specification of Mr. Underwood:

"But while the means employed for producing the desired effects may be varied, I prefer the following for general use:—I damp the paper, parchment, or other material which I desire to copy upon, with a solution of 200 grains of the yellow or neutral chromate of potash dissolved in 1 gallon of distilled water, and either use it immediately, or dry it and subsequently damp it with water as it is required for use. I then prepare the material which I use for producing the characters or marks, and which may be called copying ink, by simply dissolving (in a water bath) pure extract of logwood in distilled water; or, for printing, I use a varnish or other similar material soluble in water, and dust or throw over it powdered extract of logwood. If I desire to take twenty copies from an original, I use about six pounds of the pure extract of logwood to a gallon of distilled water; but a larger number of copies may be taken by dusting or throwing over the original, before the ink has thoroughly dried, a powder composed of five parts of powdered extract of logwood, one part of powdered gum arabic, and one part of powdered tragacanth. When I desire to print from an original, in producing which I have used ink prepared as before described, I proceed by damping six sheets of paper, prepared as before described, and having taken all superfluous moisture with good blotting paper, I place the original upon the upper sheet and press the whole for about half a minute in a copying press; I then remove the original, and in its place put six other sheets of the prepared paper in a damp state, and subject the whole to pressure for about a quarter of an hour. I then take five other prepared sheets in a damp state, and having laid the original upon them, press them together for about two minutes, then replace the original by three other prepared and damp sheets, and press the whole together for about a quarter of an hour. The extract of logwood so acts upon the neutral chromate of potash that I thus obtain twenty good clear fac-similes of the original matter or design."

They have also produced an Indian ink on the same principle, which, when used in the preparation of architectural plans, maps, &c., will give one or more clear copies of even the finest lines. The only point to be observed in the taking of such copies, is that as they are done to a scale, they must be kept pressed in close contact with the original, till they are perfectly dry, because if not they will shrink in drying, and the scale be spoilt.

The most complete information on this subject, and that of inks generally, is to be found in a memoir read before the Society of Arts, on the 15th December, by Mr. John Underwood.

COQUILLA NUTS. These nuts are produced in the Brazils by the Attaeá fumifera. They are suitable for a great variety of small ornamental works, and are manufactured into the knobs of umbrellas and parasols.

CORDAGE:—(Cordage, Fr.; Tange, Germ.) Cordage may be, and is, made of a great variety of materials. In Europe, however, it is mostly formed of hemp, although now much cordage is made of Coir. See Coir.

Professor Robinson proposed the following rule for determining the strength of cordage. Square the circumference of a rope in inches; one-fifth of the product will be the number of tons' weight which it will bear: this is, however, uncertain.

COROMANDEL WOOD. The wood of the Diospyros hirta rum. CORROSIVE SUBLIMATE, Mercury, Chloride of, or Procatochloride, (Deutschchlorure de mercur, Fr.; Actinodicque clairblêber sublim, Germ.) is made by subliming a mixture of 2½ parts of sulphate of oxide of mercury, and one part of sea-salt, in a stone-ware crucible. The sublimate rises in vapor, and encrusts the globular glass capital with a white mass of small prismatic needles. Its specific gravity is 6·225. Its taste is acrid, stypto-metallic, and exceedingly unpleasant. It is soluble in 3 parts of water, at the ordinary temperature, and in less than three times its weight. It dissolves in 2½ times its weight of cold alcohol. It is a very deadly poison. Raw white of egg swal-
COTTON MANUFACTURE.

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lowed in profusion is the best antidote. A solution of corrosive sublimate has been long employed for preserving soft anatomical preparations. By this means the corpse of Colonel Morland was embalmed, in order to be brought from the seat of war to Paris. His features remained unaltered, only his skin was brown, and his body was so hard as to sound like a piece of wood when struck with a hammer.

In the work upon the dry rot, published by Mr. Knowles, secretary of the committee of inspectors of the navy, in 1821, corrosive sublimate is enumerated among the chemical substances which had been prescribed for preventing the dry rot in timber; and it is well known that Sir H. Davy had, several years before that date, used and recommended to the Admiralty and Navy Board corrosive sublimate as an anti-dry-rot application. It has been since extensively employed by a joint-stock company for the same purpose, under the title of Ryan’s patent.

The preservative liquid known as Goadby’s solution, which is employed for preserving wood and anatomical preparations, is composed as follows:—Bay salt, 4 oz.; alum, 2 oz.; corrosive sublimate, 2 grains; water, 2 pints.

The composition of corrosive sublimate is—

<table>
<thead>
<tr>
<th>Substance</th>
<th>Amount</th>
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<tbody>
<tr>
<td>Mercury</td>
<td>100</td>
</tr>
<tr>
<td>Chlorine</td>
<td>33 3</td>
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<td></td>
<td>133 5</td>
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See MERCURY.

CORRUATED IRON. A process has been introduced for giving strength to sheet iron, by bending it into folds or wrinkles; the iron so treated is thus named.

The iron shed at the London Terminus of the Eastern Counties Railway, constructed of corrugated iron, has been described by Mr. W. Evill, jun. The entire length is 216 feet, and consists of three roofs, the centre of 36 feet span, rising 9 feet, and the side-roofs 20 feet 6 inches, with a rise of four feet.

The corrugated wrought-iron is composed of sheets No. 16 wire gauge, or 1/24 of an inch in thickness; the weight per foot is 3 lbs.; the whole weight of the centre roof of 10,335 superficial feet being scarcely 18 1/2 tons, and the side roofs, of 5,405 square feet, weigh 7 1/2 tons.

The whole roof was erected by Messrs. Walker and Sons, Bermoneys, the holders of Palmer’s patent, at a charge of £6 10s. per 100 superficial feet, including fixing, and the whole roofs cost £1,365, and might now be erected for half the cost, the patent having expired, and increased facilities existing.

Many corrugated roofs have been erected: one at St. Katherine’s Dock. At the entrance of the London Docks there is one 40 feet span and 325 feet long. On the London, Birmingham, Great Western, and other railways they have been employed.

Iron appears to have great strength given to it by this change of form; a single sheet, so thin as to be unable to bear its own vertical position, will bear 700 lbs. after corrugation without bending.

Cast-iron has been corrugated. Mr. Palmer has patented this form, and at Swansea a bridge of three arches, one of 50 and two of 48 feet span, has been erected.

COTTON AND COTTON MANUFACTURE. Fig. 198 is F. A. Calvert’s patent, toothed roller cotton gin.

\( a \equiv \) a perspective view, \( b \equiv \) a sectional view. \( A \equiv \) the box to hold seed cotton ready to be ginned; \( B \equiv \) the top of the hopper; \( C \equiv \) the fluted guard; \( D \equiv \) the fine-toothed roller; \( E \equiv \) the brush; \( F \equiv \) the discharge pipe; \( G \equiv \) a suitable block on which the machine stands.

N.B.—Over the handle in fig. 4 there is shown an arrow, indicating the direction of the motion. The handle should not be driven less than fifty turns per minute. The seed cotton should be fed into the hopper in small portions, and regularly throughout its whole length; at the same time care should be taken that a large quantity does not collect, as it will retard the operation. This gin is made from six inches to five feet wide; two persons can drive, with ease, a gin of this kind three feet wide, producing 200 lbs. of cleaned cotton per day, at the speed above stated. When driven by steam or water power at the rate of 200 revolutions per minute, it will clean 400 lbs. each foot in length per day. It is well adapted for all classes of cotton, particularly fast seed cotton, which has been valued at one penny per pound; more when done on this gin than when done on the saw gin. It will be seen that there is no hand or belt employed, hence the machine requires small power compared with other machines for like purposes.

After the cotton wool is thus separated from the seeds, it is packed in large canvas bags, commonly with the aid of a screw or hydraulic press, into a very dense bale, for the convenience of transport. Each of the American bags contains about 500 lbs. of cotton wool. When this cotton is delivered to the manufacturer, it is so foul and focky, that he must clean and disentangle it with the utmost care, before he can subject it to the carding operation.
Fig. 199, the scutching or opening machine, though usually preceded by the willow, is often the first machine in a mill through which the cotton is passed, and serves, as its name implies, to open the matted locks of cotton and separate its fibres, and at the same time to remove a large percentage of the seed and dirt which may have been packed with it.

The cotton is placed upon the travelling creeper marked a, which is made of a number of narrow slips, or laths, of wood, screwed to three endless bands of leather, the pivots of which are marked b and c. Motion is given to the roller e, by a wheel on the end of the feed roller, thus causing the creeper to advance, carrying with it the cotton to the feeding rollers d; these revolving slowly pass the cotton to the second smaller pair of fluted rollers, which serve it to the beater.

The top feeding rollers are weighted by levers and weights e e, and hold the cotton sufficiently tight for the beater to act upon it.

The beater is placed inside the machine at f, and extends quite across its breadth, its shaft or axis being shown with the speed fully upon it at g. The form of the beater varies, but we give the following as an example:

On a shaft are placed four or five spiders, each having three or four arms; to the ends of these arms are attached steel blades, which pass along the whole length of the beater; two of the arms being shorter than the other arms of the spider, allow two of the blades to contain a double row
of spikes in each, the points of the spikes being at the same distance from the axis as the other two blades. As the beater revolves about 800 turns per minute, the blades and spikes strike the cotton with considerable force as it is passed from the feeding rollers, and thus free it from many of its impurities.

Immediately under the feed rollers and beater, are placed a number of wedge-shaped bars, which form a semi-circular grid, through the narrow openings of which the dirt and seeds fall to the floor, their removal being effected through the doors in the framing. To prevent the cotton passing with the dirt through the grid, a current of air to draw the cotton from the beater to the cage, is produced by an exhaust fan (its axis being shown at \( k \)) receiving its motion from a pulley on the beater shaft. The projection \( i \) on the framing forms a pipe, through which the fan draws the air from the beater, passing on its way through a large revolving cage or cylinder, the periphery of which is formed of sheets of perforated metal, or wire gauze. Its axis is shown at \( k \).

From the cage the cotton is delivered by a second travelling creeper and falls into a receptacle, from which it is weighed and made ready for the operations of the lap machine.

*Figs. 201, 202,* represent skeletons of the old cards, to facilitate the comprehension of these complex machines. *Fig. 201* is a plan; \( F \) is the main cylinder; \( M M \) is the doffer knife or comb; \( a \), the carded fleece hemmed in by the funnel \( a \), pressed between the rollers \( b \), and then falling in narrow fillets into its can. *Fig. 202*, \( K L \) are the feed rollers; \( A B \), the main cylinder; \( C D \), the tops; \( E F \), the doffer card; \( M N \), the doffer knife; \( D, B, E \), the card-end passing between compressing rollers into the can \( a \).
Fig. 203 is a carding-engine without top flats, being entirely covered with rollers and cleaners; it is suitable for all counts under forties, and will card for 600 lbs. of twenties per week of 60 hours.

It is made by Hetherington & Sons, Manchester, entirely of iron, and may be looked upon as a very complete engine.

Fig. 204 represents the combing machine, as seen at work in the mills of Thomas Baxley, Esq., M. P., Manchester, and other fine spinning concerns. The introduction of this beautiful machine, manufactured by Messrs. Hetherington & Sons, Manchester, having produced a complete revolution in the preparation of fine yarns, we give a brief history of its invention prior to describing it in detail.

About the year 1844, Mr. Jean Jacques Bourcart, one of the partners of the eminent
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The firm of Messrs. Nicolas Schlumberger & Co., of Guebwiller, in the department du Haut Rhin in the kingdom of France, offered a prize of a considerable sum of money to any person who should invent a machine that would supersede the carding engine in the treatment of the fibres of cotton, suitable for fine numbers, such machine to be free from the objections urged against the carding engine of breaking the fibres of the cotton, and delivering them in the staple or hook form; and besides this, it was to possess the peculiar property of separating the long fibres from the short ones; and after laying the long fibres parallel to each other, pass them out of the machine in a perfectly cleaned state in the form of a sliver ready for the drawing frame.

In a short time after this announcement Mr. Bourcart was waited upon by Mr. Josée Heilman, of Mulhausen, in the department du Haut Rhin in the kingdom of France, machine maker, who informed him that he claimed the prize. Mr. Heilman, feeling satisfied that his invention was a valuable one, made application for a patent in England, which patent was sealed on the 25th of February, 1846.

The specification of Mr. Heilman's invention is very clear and concise, and a single extract from it will be sufficient to convey to the mind of the practical spinner the nature and object of his invention. He says:—"My invention consists, secondly, in a new combination of machinery for the purpose of combing cotton, as well as wool and other fibrous materials, into which machine the fibres as they come from the dressing-machine are introduced in a lap sliver or fleece, which is broken asunder, and the fibres are combed at each end, and the long and short fibres are separated, the long ones being united in one sliver, the short ones in another, and they are passed out of the machine thus separated ready for drawing, roving, and other subsequent operations." Mr. Heilman did not live long enough to reap the reward of his genius for inventing this and other important machines, and his son, Jean Jacques Heilman, was under the necessity of bringing an action for the infringement of the combing machine patent against certain parties in Yorkshire; the trial took place before the Lord Chief Justice of the Queen's Bench and a special jury at the Guildhall, London, on the 27th and 28th of February, 1852, which resulted in a verdict for the plaintiff, thereby establishing the validity of the patent. Since that period a considerable number of machines have been set to work in this country; and although several patents have been taken out for certain improvements introduced into these machines, still the combination of a delivering, combing, and drawing apparatus, and their mode of action, is retained, as will be seen in the following description of Cross Section of Combing Machine, fig. 204.

1. Is the lap of cotton resting upon the two wooden rollers 2, 2a. When motion is given to these rollers, they cause the lap to unwind and deliver the sheet of cotton down the inclined conductor 3, and between the fluted steel feeding roller 4, and the leather-covered pressure roller 4a; to these rollers an intermittent motion is given by means of a star wheel; they make 1/6 of a revolution to one revolution of the cylinder 6, this motion being effected during the time the cushion plate 5a is forward, and the nipping plate 5 is lifted from it. The cushion plate 5a is hung upon the centre 5', and the nipping plate upon the shaft 5c, and this shaft receives motion from a cam at the end of the machine through the lever 5e, the connecting rod 13d, lever 13e, and shaft 13b,—the parts being so arranged that the cushion plate 5a is pressed backward by the nipping plate 5, but as soon as the pressure is removed it is drawn forward by a spring until it arrives at the strap. Besides this movement, the nipping plate is caused to move on its own axis, which enables it to quit contact with the cushion, while the cotton is being fed in between them.

In the engraving (fig. 204) the cushion 5a is represented as thrown back by the nipping plate 5, and while in this position the cotton is held between them, until the combs on the cylinder pass between the fibres of cotton which protrude, and remove from them all impurities and the fibres which are too short to be held by the nipper. The combing cylinder 6a is attached to the shaft, or axis 6, by which it is caused to revolve. The periphery of this cylinder is divided into four unequal parts by the combs 6b on one side, and the fluted segment 6c on the other side; the spaces between them being plain to allow time for the nipper and leather detaching roller 8a to change their positions. The combs on the cylinder are made with teeth at various distances, the coarser ones taking the lead, and finer teeth following, the last combs having more than 80 teeth in a linear inch. All impurity or waste mixed with the fibres held by the nipper is carried away by these combs, which at every revolution are cleaned by the cylindrical brush 10a, stripping the waste from them, and depositing it upon the travelling creeper 11a, formed of wired cloth, which carries it down until the dollying knife, or steel blade 12, removes it in the usual manner; it then drops into a waste box, and is afterwards worked into coarse yarns. A cylinder covered with wired cloth is sometimes used instead of the travelling creeper, and acts in a similar way.

As soon as the combs have all passed the fibres held by the nipper, the cushion plate 5a is drawn forward, and the nipping plate 5 is lifted from it, and thus releases the fleece; the fluted segment 6c on the cylinder is at the same time passing immediately under the cushion.
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Plate 5a, the ends of the combed fibres lying upon it, and as the leather detaching roller 8a has been lowered into contact with the fluted segment, they are then drawn forward; but as it is necessary to prevent any fibres passing that have not been properly cleaned or combed, the top comb 7 is placed between the nipper and the roller, and as this comb falls and penetrates the fleece just in front of the part uncombed by the cylindrical combs, it prevents any waste from being drawn forward with the tail end of the clean fibres.

The leather detaching roller 8a, in addition to its occasional contact with the fluted segment 6c, is always in contact with the fluted steel detaching roller 8, and participates in its movements.

These rollers are stationary while the cylinder combs are cleaning the fibres projecting from the nipper, but as soon as that operation is completed, they are put into motion, and make part of a revolution backward, taking back with them the fibres previously combed, but taken out of the way to allow the cylinder combs to pass, in order for the next fibres coming forward to be joined or pieced to them, so as to form a continuous sliver or ribbon.

As soon as the backward movement is completed, the leather detaching roller 8a is made to approach the cylinder by the lever 87, which receives motion from a cam at the end of the machine, through the lever 8d, connecting rod 8e, lever 14e, and shaft 14b. Before, however, it comes in contact with the fluted segment 6c, the movement of the fluted roller is reversed, and it is caused to turn forward, producing a corresponding movement of the detaching roller 8a, the speed being so arranged that, before they are allowed to touch each other, the peripheries of the fluted segment 6c and the roller 8a travel with an equal velocity. At this stage, the ends of the fibres cleaned by the cylinder combs and projecting from the nipper, are resting upon the fluted segment; and the roller 8a, in coming in contact with it, presses upon these fibres, and immediately draws them forward; the front ends are then lifted by the leather roller and placed on the top of those fibres previously cleaned, and brought back to receive them. The pressure of the rollers 8 and 8a completes the piecing of the fibres; the motion of the rollers being continued until the tail end of the fibres is drawn through the top comb, and a length of fibres is delivered to the calender rollers, sufficient slack being left between to allow for the next backward movement. The roller 8a is then raised from the fluted segment and ceases to revolve.

The calender rollers, the combed cotton passes along the front plate or conductor, where it joins the slivers from the other five heads of the machine, and with them passes through the drawing head, and is then deposited in a can ready to be removed to the drawing frame.

The movements above described being necessary for each beat of the combing machine, they must all recur each second of time, or sixty times each minute.

Recapitulation.—The combing machine is fed or supplied from 6 laps of cotton, (each lap being formed from about 18 slivers from the breaker carding engines, and doubled into a lap in the lap machine.) Each lap is 8 inches wide and about 12 inches diameter when full.

The following description of the manner in which the combing machine works is confined to one head supplied by 1 lap, as each of the 6 heads shown in fig. 204 is exactly like the others:

The lap of cotton having been placed on a pair of revolving lap rollers, the fleece, or sheet of cotton, is conducted down an inclined guide to a fluted steel feeding roller, which places the cotton between the open jaws of an iron nipper. The nipper is then closed and made to approach the comb cylinder, by means of a cam, where it holds the fibres in such a position that the combs of the revolving cylinder pass between and remove from the fibres all impurities and short or broken cotton, which are afterwards worked up into yarns of a coarser quality.

As soon as the combs have all passed through the cotton, the nipper recedes from the cylinder, and as soon as it has reached the proper distance, opens its jaws, and allows the partially combed fibres to be drawn out of the fleece, by means of a leather-covered roller, which works for this purpose in contact with the fluted segment on the comb cylinder, and with the fluted steel detaching roller. The drawing out of these fibres causes the ends of those fibres which were before held in the nipper to pass between the teeth of a fine top comb, this completing the combing of each separate fibre. Previous to the movement for drawing out the fibres from the uncombed fleece, the detaching roller has made a partial revolution backwards, and taken with it the combed cotton previously delivered, in order to piece it to the fibres just combed.

The machine is so arranged that the forward movement of the detaching roller overlaps the ends, and brings out the cotton in a continuous sliver to the front of the machine, where it joins the other five slivers which have been simultaneously produced on the other heads of the machine. The united slivers then pass through the drawing head to the next operation—the drawing frame. (See Vol. 1.)

Fig. 204a is a drawing frame, by Hetherington & Sons, containing all the latest improvements, i. e., greater strength of materials; a stop motion to stop the frame, when
a silver breaks; a roller plate to prevent roller laps. The coiler motion, by means of which the sliver is placed in the can in circles overlapping each other on the principle described.

in fig. 204a, the can roving frame; 4 rows of draught rollers instead of 3; and lastly, an apparatus for lifting all the roller weights from off the rollers at any time when the frame may be stopped.

The stubbing frame (fig. 2046) is the first machine which puts twist into the silver, and prepares it for the roving frame, which in its principle it precisely resembles.

The preliminary spinning process is called roving. At first the torsion is slight in proportion to the extension, since the solidity of the still coarse sliver needs that cohesive aid only in a small degree, and looseness of texture must be maintained to facilitate to the utmost the further elongation.

Fig. 205 shows the latest construction of a bobbin and fly frame, as made by Messrs. Higgins & Sons, of Manchester. As the principle of action is similar to that already described, it only needs to add that many improvements have been introduced by the makers, as will be seen on reference to the engraving. 1 represents a front view of the frame; 2 a view of the back of the frame; 3 shows the driving pulley and gearing end; and 4 the same end with the iron casing removed, so as to exhibit the works inside.

The spindles and bobbins being now driven by gearing instead of by bands as formerly, and greater strength of materials being introduced throughout the frame, it is capable of producing a better quality with an increased quantity of rovings than was possible formerly.

Fig. 206 also represents a similar frame for rovings, made by Hetherington & Sons. Its action is the same as that already described.

Fig. 207 is a view of one of the most improved forms of the throstle frame by Messrs. Hetherington & Sons, Manchester.
The Self-Acting Mule.—In a previous edition of this work, mention was made of the patent self-acting mules of Mr. Roberts, of Manchester, and of Mr. Smith, of Deanstone. Since the period when that notice was written a great number of patents have been obtained for improvements on the original patents, by Mr. Porter, of Manchester, Messrs. Higgins & Whitworth, of Salford, Mr. Montgomery, of Johnstone, Messrs. Craig & Sharp, of Glasgow, and many others.

Mr. Roberts's self-acting mule, which was practically the first introduced, has maintained its ground against all competitors, and is still the mule which is most extensively used and approved in the cotton trade.

As might be expected, it has undergone a variety of improvements and alterations by the various machine workers who have made it since the expiration of the patent, but by none more than by Messrs. Parr, Curtis & Makedly, of Manchester, who have devoted a large amount of time and expense in its perfection.

They are the proprietors of six patents for this mule, the invention of Mr. Curtis, of the manager Mr. Lakin, and of Messrs. Rhodes & Wain, the combination of which has enabled that firm to produce a very superior self-acting mule, and given them a decided lead as makers.

The following are some of the principal improvements they have effected: viz., substituting a catch-box with an eccentric box, in lieu of a cam shaft, to produce the required changes; an improved arrangement of the faller motion, which causes the fallers to act more easily upon the yarn, and not producing a recoil in them when the "backing-off" takes place, thus preventing "snarls" and injury to the yarn; in applying a spiral spring for the purpose of bringing the backing-off cones into contact, by which the operation of "backing-off" can be performed with the greatest precision. The backing-off movement is also made to stop itself, and to cause the change to be made which affects the putting-up of the carriage, which it does in less time than if an independent motion was employed. They have also an arrangement for driving the back, or drawing-out shaft, by gearing, in such a manner that, in the event of an obstruction coming in the way of the carriage going out, the motion ceases and prevents the mule being injured. By means of a friction motion, the object of which is to take the carriage in to the rollers, the carriage will at once stop in the event of any obstruction presenting itself. For the want of an arrangement of this nature, lives have been lost and limbs injured, when careless boys have been cleaning the carriage whilst in motion, and have been caught between it and the roller beam, and thus killed or injured.

Another improvement consists in connecting the drawing-out shaft and the quadrant pulley shaft by gearing, instead of by bands, thereby producing a more perfect winding-on, as the quadrant is moved the same distance at each stretch of the carriage. They have also made a different arrangement of the headstock—or self-acting portion of the mule—causing its height to be much reduced, which makes it more steady, offers less obstruction to the light, enables the spinner to see all the spindles from any part of the mule, and allows a larger driving strap, or belt, to be used, which in low rooms is of considerable importance. The result of these various improvements is the production of one of the most perfect spinning machines now in the trade.

For spinning very coarse numbers, say 6's, they have patented an arrangement, by which the rotation of the spindles can be stopped, and the operation of backing-off performed, during the going out of the carriage, thus effecting a considerable saving of time.
Some of their mules are working in the mills of Messrs. Thomas Mason & Son, Ashton-under-Lyne, and are making five to five-and-a-half draws per minute, the length of the stretch being 67 inches—a speed and length of stretch never previously attained.

The following is a description of one of these excellent mules:—

Fig. 208 is a plan view, fig. 209 a transverse section, and fig. 210 an end view of so much of a mule as is requisite for its illustration here.

As there are many parts which are common to all mules, most of which have been previously described in the notice of the hand mule, we shall therefore only notice the more prominent portions of the self-acting part of the mule. Among such parts are: the framing of the headstock a; the carriage b; the rovings c; the supports d of the roller beam e; the curved rollers c; the carriage wheels b; the slips or rails, b, on which they move; the faller wire b; the counter-faller wire b. The following
are the parts chiefly connected with the self-acting portion of the mule.—The fast pulley \( r \), the loose pulley \( s \), the bevels \( r' \) and \( s' \), which give motion to the fluted rollers; the back, or drawing-out shaft \( g \), wheels \( q' \) and \( q \), by which, through the shaft \( o' \) and wheels \( o' \) and \( o \), motion is communicated to the pinion \( o \) on the shaft \( o' \), and thence to the quadrant \( o' \). The scroll shaft \( n \), the scrolls \( n' \) and \( n'' \), the catch-box \( k' \), for giving motion through the bevel wheels \( n' \) and \( n'' \) to the scroll shaft. Drawing-in cord \( n'' \). Screw in radial arm \( i \), nut on same \( r' \), winding-on chain \( r' \), winding-on band \( r' \), drawing-out cord \( i' \). Pinion \( r' \) on front roller shaft, to give motion through the wheels \( i' \), \( i' \), and \( i' \), to drawing-out shaft \( a \). Pinion \( i' \), and wheels \( j' \), \( j' \), and \( j' \) for giving motion to shaft \( j' \); pinion \( j' \), giving motion to backing-off wheel \( j' \). On the change shaft \( k \) is keyed a pinion which bears with the wheel \( j' \), and receives motion therefrom. One-half of the catch-box \( k' \) is fast to one end of a long hollow shaft on which are two cams, one of which is used to put the front drawing roller catch-box \( k' \) into and out of contact; the other is used for the purpose of traversing the driving strap on or off the fast pulley \( r \) as required. The other half of the catch-box \( k' \) is placed on the shaft \( k \), a key fast on which passes through the boss of the catch-box, and causes it to be carried round by the shaft as it rotates. Though carried round with the shaft, it is at liberty to move lengthwise, so as to allow it to be put into and out of contact with the other half when required. The spiral spring \( k' \) is also placed on the shaft \( k \), and continually bears against the end of the catch-box next to it, and endeavors to put it in contact with the other, which it does when permitted and the changes are required. The change lever \( k' \) moves on a stud which passes through its boss \( a' \); near which end of this lever are the adjustable pieces \( a' \). When the machine is put in motion, supposing the carriage to be coming out, the driving strap is for the most part on the fast pulley \( r \) when motion is given through the bevel wheels \( s' \) and \( s'' \) to the drawing rollers \( a' \), which will then draw the rovings \( c' \) off the bobbins, and deliver the slivers so drawn at the front of the rollers; and the same being fast to the spindles, as the carriage is drawn out the slivers are taken out also, and as the spindles at this time are turned round at a quick rate, (say 6,000 revolutions per minute,) they give twist to the slivers and convert them into yarn or twisted threads. Motion is communicated to the spindles from the rim pulley \( r' \), through the rim band \( r' \), which
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passes from the rim pulley to a grooved pulley on the tin roller shaft, round which it passes, and thence round the grooved pulley $b$ back to the rim pulley, thus forming an endless band. It will be seen that the rim band pulley and the other pulleys, over or round which the rim band passes, are formed with double grooves, and the band being passed round each, it forms a double band, which is found of great advantage, as it will work with a shacker band than if only one groove was used; there is consequently less strain on the band, and it is longer. A string or cord passes round the tin roller to a wharve on each spindle, round which it passes, and thence back to the tin roller, and thus, when the tin roller receives motion from the rim band, it gives motion to the spindles. The carriage is caused to move outwards by means of the cord $a$, one end of which is attached to a ratchet pulley fixed on the carriage cross, or square $l$, and is then passed over the spiral grooved pulley $l^2$ fast on the drawing-out shaft $b$, and passes thence under the guide pulley $l^3$ round the pulley $l^4$ to another ratchet pulley, also on the carriage square, where the other end is then fastened. The cord receives motion from the pulley $l^2$, round which it passes and communicates the motion it receives to the carriage, the carriage wheels $b^3$ moving freely on the slips $b^4$.

When the carriage has completed its outward run, the bowl $a^3$ on the counter faller shaft comes against the piece $a^4$, depresses it and the end of the lever $a^5$ to which it is attached, and raises the other end, and with it the slide $c$, on which are two inclines. A round pin (not seen) passes through the boss of the catch-box next to the slide, and bears against the sliding half of the catch-box, and holds it out of contact.

When the slide $c$ is raised, the part of the incline which bore against the pin and kept the catch-box from being in contact, is withdrawn, on which the spring puts them in contact, and motion is given to the hollow shaft, and the camms thercon; one of which causes the catch-box $x$ to be taken out of contact when motion ceases to be given to the drawing rollers and to the going out of the carriage; and the other causes the driving strap to be traversed off from the fast pulley on to the loose one when motion ceases to be given to the rim pulley, and thence to the spindles. The inclines on the slide are so formed that, by the time the shaft has made half a revolution, they act on the pin and cause it to put the catch-box out of contact. The next operation is the backing-off or uncoiling the threads coiled on the spindle above the cop, which is effected by causing the backing-off cones attached to the wheel $s^3$ to be put into contact with one formed in the interior of the fast pulley $s$, when a reverse motion will be given to the rim pulley and thence to the tin roller and the spindles.

The backing-off cones are put into contact by means of a spiral spring, which, when the strap fork is moved to traverse the strap on to the loose pulley, it is allowed to do. Simultaneously with the backing-off, the putting down of the faller wire takes place, which is effected through the reverse motion of the tin roller shaft, which causes the catch $e^1$ to take into a tooth of the ratchet wheel $e^2$, when they will move together, and with them the plate $e^3$, to a stud in which one end of the chain $e^4$ is fastened, the other end of which is attached to the outer end of the finger $e^5$, fast on the faller shaft. When this chain is drawn forward by the plate, it draws down the end of the finger $e^5$ to which it is attached, and thence, partially turns the faller shaft and depresses the faller wire $b^5$, and, at the same time, raises the lever $e^6$, the lower part of which bears against a bow attached to a lever which rests on the builder rail $c^6$. As soon as the lever $e^6$ is raised sufficiently high to allow the lower end to pass over, instead of bearing against the bow, it is drawn forward by a spiral spring, which causes the backing-off cones to be taken out of contact, when the backing-off ceases, and the operations of running the carriage in and winding the yarn on to the spindles must take place. When the cones are taken out of contact, the lower end of the lever $x$ is withdrawn from being over the top of the lever $x^4$, leaving that lever at liberty to turn, and the catch-box $n^3$ thereupon drops into gear, and motion is communicated to the scrolls $n^2$ and $n^3$, and to the cords $n^4$ and $n^5$. The cord $n^6$ is at one end attached to the scroll $m^1$, and passes thence round the pulley $n^7$ to the ratchet pulley $n^8$ fixed to the back of the carriage square. The cord $n^7$ is at one end attached to the scroll $n^2$, and passes thence round the pulley $n^1$ to the ratchet pulley $n^2$ fixed to the front of the carriage square. It will thus be seen that the carriage is held in one direction by one band, and in another by the other band, and that it can only be moved in either direction by the one scroll giving off as much cord as the other winds on. When the catch-box $n^3$ drops in gear, the scroll $n^3$ winds the cord $n^7$ on, and draws the carriage in. It will thus be seen that the carriage is drawn out by means of the back or drawing-out shaft $b$, and is drawn in by the scroll $m^1$. The winding on of the thread in the form of a cop is effected by means of Mr. Roberts's ingenious application of the quadrant or radial arm $o^2$, screw $l$, and winding-on chain $t^2$ and band $r^2$. The chain $t^2$ is at one end attached to the nut $l$ and at the other to the band $r$. During the coming out of the carriage, the drawing-out shaft, through the means of the wheels $o^1$, $o^2$, $o^3$ and $o^4$, shafts $g^2$ and $g^3$, and pinion $o^5$, moves the quadrant which, by the time the carriage is quite out, will have been moved outwards a little past the perpendicular. The chain is wound on to the barrel by means of the cord $o$, which,
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being fixed and lapped round the barrel as the carriage moves outward, causes it to turn. On the barrel is a spur wheel which gears into a spur pinion on the tin roller shaft, (these wheels, being under the frame side, are not seen in the drawing.) The spur pinion is loose on the tin roller shaft, and as the carriage comes out it turns loosely thereon, but as the carriage goes in, the chain is turns the barrel round, and with it the spur pinion. A catch on a stud fixed in the side of the pinion, at that time taking into a tooth of the ratchet wheel fast on the tin roller shaft, the motion of the spur pinion is communicated to the tin roller shaft, and thence to the spindles, causing the thread or yarn spun during the coming out of the carriage to be wound on the spindles, in the form of the cop, while the carriage goes in. At the commencement of the formation of a set of cops, when the yarn is being wound on the bare spindles, the spindles require to have a greater number of turns given to them than they do when the cop bottom is formed. To produce this variation, the following means are employed:—At the commencement of each set, the screw in the radial arm is turned so as to turn the nut to the bottom of the screw, where it is near to the shaft on which the quadrant moves; consequently little or no motion is given to the chain, and the carriage, as it goes in, causes the chain to be drawn off the band. As the formation of the cop bottom proceeds, the screw is turned and the nut is raised; by which means a less quantity of chain is drawn off the barrel; the chain, at the point of attachment, gradually following the carriage as it goes in.

During the going in of the carriage the quadrant is drawn down or made to follow the carriage by the chain pulling it, the speed at which it is allowed to descend is regulated by the motion of the carriage; the quadrant, during the going in of the carriage, through the pinion a, shafts c and o, and wheels a, a, a, and o driving the drawing-out shaft.

When the carriage has completed its inward run, the bowl a comes in contact with the piece a, and depresses it and the end of the lever k to which it is attached, and also the slide c, which then allows the catch-box k to be put in contact, and causes the cam shaft to make another half revolution. During this half revolution of the cam shaft, the cams cause the catch-box 17 to be put in contact, and the driving strap to be traversed on to the fast pulley, and, by the latter movement, the catch-box 16 is taken out of gear and the winding-in motion of the scrolls ceases, and the carriage will again commence its outward run, and with it the spinning of the thread.

Fig. 211 is a view of a beetling machine, made by Mr. Jackson, of Bolton, for the firm
of Messrs. Bridson, Son & Co., of that town. A is the bectling roller, and b, c are the rolls of cloth which are to receive the peculiar finish, which bectling alone can give to cotton cloths.

Although this is a very simple machine, yet it is questionable if it or any other modern invention can effectually take the place of the old-fashioned but useful upright wooden bectle.

The following extracts from the circular of Messrs. Leasing & Co. present so complete a view of the state of the cotton trade at this date, that they are now and will continue of much interest and importance:

"The close of the commercial year, ending the 31st of August, gives the total receipt of cotton at all the American ports as 3,113,962 bales, against 2,989,679 bales of the year previous. Of the past year's receipts, England took 1,809,966 bales, the rest of Europe 780,489 bales, while the United States bought 595,652 bales. This shows an increase to Great Britain, a falling off in the exports to the Continent and other parts, and a diminished consumption in the United States.

"It is important to remark, that this falling off in the exportation to the Continent of Europe, and also the home consumption, does not necessarily involve any actual diminution in consumption; because, what the Continent of Europe failed to take direct of the raw material, will be represented by increased re-exports from Liverpool, and increased demands for yarns from the English spinner; and what the United States failed to buy and work up, has been bought and will be worked up by others. Consequently, although on the surface a falling off in consumption may appear as in regard to the Continent and America, the demand will be supplied through other channels in a proportionately increased rate.

"Added to this established consumption, is the natural increase throughout the world in excess of supply. The opening up of China, and the mutiny in India, which, by interrupting not only the growth of cotton there, but also the weaving industry of the natives, have increased the demand for yarns and cloths from England, censure to add to the demand for our staple. The last large receipts of Suratts from India occurred during the blockade of the Chinese ports; consequently the exports from Bombay, usually sent to China, were, by this cause, thrown upon the Liverpool market, induced also by the attraction of high prices.

"The universal prevalence of the panic, the long-continued prostration in trade, and the working of short time, have reduced the stocks of goods everywhere, and this special feature is met in the markets of the raw material with a similar exhaustion. The reports in regard to the growing crop are conflicting. What with the certain effect of the floods in the Mississippi Valley, and the information from various sources in regard to the injury the young plant is receiving, serious apprehensions are entertained of another comparatively short crop. It is worthy of remark that conflicting interests generally take opposite views in regard to the future prospects of the growing crop. The hopes and apprehensions of the buyer and seller, combined with the natural disposition to embrace that view which is dictated by self-interest, must continue to characterize all the reports upon cotton, either from Europe or this side. But it is well for our European friends to have clearly before them the utmost cotton crop America can yield under the best possible conditions embraced in a wide area under cultivation, an early spring, a good stand in the field, a propitious summer, and a favorable autumn. Accepting these rare conditions as embraced within any one year, it is simply impossible for the United States to produce for commercial purposes, with the present supply of labor, beyond a certain amount of cotton. As the best standard by which to arrive at this capacity for 'utmost production' in America, we select the year 1855-56. The commercial crop that season was 3,627,845 bales, from which must be deducted for cotton remaining over from the year previous, on hand in the interior, or in stock on the seaboard, say 250,000 bales. This leaves as the 'actual' or 'new' crop of 1855-56 the reduced amount of 3,277,845 bales. The season here taken, will be remembered as the most favorable ever known to a large production. It was also stimulated in its growth by previously ruling high prices. Accepting as correct the generally-received data that the negro labor force in the cotton States increases at the rate of five per cent. per annum, would give fifteen per cent. Increase for the three years, from 1856 to 1858-59. This increase of labor thrown into the cotton yield would seem to indicate 3,760,000 bales (more or less) as the utmost possible capacity of production for the year ending 1st September, 1859. In explanation, it is worthy of remark that the increase upon the increase, which we have not estimated, in the three years, would make the production even larger. Yet we see in the succeeding years a falling off from the production of 1855-56 instead of an advance. The total commercial crop of 1856-57 was only 3,289,919 bales, while the season just closed gives the limited yield of 3,113,962 bales.

"The production of cotton in America is not therefore limited by soil. It is a question
of labor, the negroes being almost exclusively the producers. Now a negro can only "pick" so many pounds of cotton a day, and no more. There is a certain number of negroes; and these cannot be added to otherwise than by the natural increase of population already estimated. They cannot be increased by immigration. The cotton picking season—that is, the cotton harvest—cannot extend beyond a certain number of days. Estimating, therefore, the largest number of negro laborers, the greatest amount of cotton per day to the hand, and the longest possible extension of the harvest or picking season, and we have the utmost possible production of the new crop. As before stated, the cotton year of 1833-56 presented all these favorable characteristics. Since then, the crop has been reduced in exact proportion as either of these features were affected. In illustration, the following statement is instructive:

In 1834 the first receipt of new cotton on the sea board was on the 23d of July, the receipts at New Orleans on the 1st of September being 6,720 bales. The crop that year was considered large, being 2,594,563 bales.

In 1846 the first receipt of new cotton was on the 7th of August, and the receipts at New Orleans on the 1st of September only 140 bales! Here notice the falling off in the total crop that year, the same being only 1,778,651 bales.

In 1848 we have a receipt on the 1st of September at New Orleans of 2,864 bales, and a total crop of 2,788,966 bales.

In 1849 (the succeeding year) we find the receipts at New Orleans on the 1st of September to be only 477 bales, and the crop for that year falling off to 2,096,706 bales!

In 1851 we find an unusually early receipt of the first bale and a receipt of new cotton at New Orleans on the 1st of September of over 3,000 bales! The crop that year was the largest ever grown up to that period, being over 3,000,000 bales.

In 1852 (the succeeding year) we find the receipts at New Orleans on the 1st of September to be 5,077 bales, being the largest crop ever known up to that time; followed in exact ratio by the largest crop ever grown, being 3,262,882 bales.

In 1853 we have a late receipt, followed by a diminished crop.

In 1854 we have another small receipt on the 1st of September, with a small total crop.

In 1855 we find an unusually early receipt of cotton, with the receipts at New Orleans on the 1st of September amounting to the unexampled figure of 23,832 bales! An increased crop follows this early heavy receipt, being over 3,500,000 bales.

In 1856 (the next year) the receipts at New Orleans on the 1st of September were only 1,106 bales, and the crop, true to the principle of Labor, on which it depends so much, fell to 2,938,781 bales.

In 1857 the receipt on the 1st of September of new cotton at New Orleans was only 33 bales, followed by a short crop.

In this year the receipts up to date at New Orleans figure up 4,824 bales, embracing, of course, the flooded districts.

"Referring to our annual tabular statement, it will be found that the ratio of increase in consumption keeps pace with increase of production, if indeed it does not exceed the latter."

---

**Growth and Consumption of the United States.**

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<tr>
<th>Years</th>
<th>New Orleans</th>
<th>Florida</th>
<th>Alabama</th>
<th>Texas</th>
<th>Georgia</th>
<th>South Carolina</th>
<th>North Carolina</th>
<th>Virginia</th>
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<th>Consumed and in Spinners' hands</th>
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## COTTON MANUFACTURE.

### Price of Cotton, at Liverpool, at the close of each Year.

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<th>1841</th>
<th>1842</th>
<th>1843</th>
<th>1844</th>
<th>1845</th>
<th>1846</th>
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<td>24</td>
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</tr>
<tr>
<td>Stained dito</td>
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</tr>
<tr>
<td>Upland</td>
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<td>13</td>
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<td>17</td>
<td>19</td>
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</tr>
<tr>
<td>Mobile</td>
<td>34</td>
<td>36</td>
<td>38</td>
<td>40</td>
<td>42</td>
<td>44</td>
<td>46</td>
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</tr>
<tr>
<td>New Orleans</td>
<td>64</td>
<td>66</td>
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<td>70</td>
<td>72</td>
<td>74</td>
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<td>80</td>
</tr>
<tr>
<td>Peruvian</td>
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<td>12</td>
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<td>19</td>
<td>21</td>
<td>23</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>Demerara, &amp;c.</td>
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<tr>
<td>Common West In.</td>
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<td></td>
</tr>
<tr>
<td>Louisiana, &amp;c.</td>
<td></td>
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<td></td>
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<tr>
<td>Smyrna</td>
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<td>55</td>
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<td>63</td>
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<td>69</td>
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<td>Bengal</td>
<td>57</td>
<td>59</td>
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<td>72</td>
</tr>
<tr>
<td>Madras</td>
<td>57</td>
<td>59</td>
<td>61</td>
<td>63</td>
<td>64</td>
<td>66</td>
<td>68</td>
<td>70</td>
<td>72</td>
</tr>
</tbody>
</table>

### Price of Water and Mule Twist, in Manchester, on the 31st of December in each Year.

<table>
<thead>
<tr>
<th>Mule Twist</th>
<th>No.</th>
<th>1840</th>
<th>1841</th>
<th>1842</th>
<th>1843</th>
<th>1844</th>
<th>1845</th>
<th>1846</th>
<th>1847</th>
<th>1848</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Seconds</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
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<tr>
<td>Best Seconds</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Water Twist</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
</tbody>
</table>

### Notes: (In the above tables, British cotton has been treated separately.)
COTTON MANUFACTURE.

The Growth, Consumption, and Export of Cotton from the United States during the last Fifteen Years.

<table>
<thead>
<tr>
<th>Years</th>
<th>Crop of the United States</th>
<th>Consumption in the United States</th>
<th>Exported to</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Great Britain</td>
<td>France</td>
</tr>
<tr>
<td>1844-45</td>
<td>2,264,645</td>
<td>359,666</td>
<td>1,439,004</td>
<td>329,357</td>
</tr>
<tr>
<td>1845-46</td>
<td>2,106,627</td>
<td>426,257</td>
<td>1,162,369</td>
<td>323,783</td>
</tr>
<tr>
<td>1846-47</td>
<td>2,178,541</td>
<td>457,247</td>
<td>1,365,265</td>
<td>325,809</td>
</tr>
<tr>
<td>1847-48</td>
<td>2,347,294</td>
<td>616,444</td>
<td>1,397,342</td>
<td>372,132</td>
</tr>
<tr>
<td>1848-49</td>
<td>2,728,563</td>
<td>716,255</td>
<td>1,387,201</td>
<td>302,258</td>
</tr>
<tr>
<td>1849-50</td>
<td>2,669,268</td>
<td>615,208</td>
<td>1,166,771</td>
<td>209,667</td>
</tr>
<tr>
<td>1850-51</td>
<td>3,205,207</td>
<td>453,614</td>
<td>1,406,785</td>
<td>309,358</td>
</tr>
<tr>
<td>1851-52</td>
<td>3,103,629</td>
<td>669,609</td>
<td>1,065,749</td>
<td>421,835</td>
</tr>
<tr>
<td>1852-53</td>
<td>3,262,882</td>
<td>865,725</td>
<td>1,478,685</td>
<td>394,728</td>
</tr>
<tr>
<td>1853-54</td>
<td>2,830,272</td>
<td>737,596</td>
<td>1,068,756</td>
<td>374,638</td>
</tr>
<tr>
<td>1854-55</td>
<td>3,041,420</td>
<td>769,614</td>
<td>1,080,716</td>
<td>409,691</td>
</tr>
<tr>
<td>1855-56</td>
<td>3,057,348</td>
<td>911,729</td>
<td>1,301,986</td>
<td>340,057</td>
</tr>
<tr>
<td>1856-57</td>
<td>2,889,319</td>
<td>919,936</td>
<td>1,082,926</td>
<td>359,002</td>
</tr>
</tbody>
</table>

Cotton Crop of the United States.

<table>
<thead>
<tr>
<th>Years</th>
<th>1837</th>
<th>1838</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Orleans</td>
<td>1,433,060</td>
<td>1,576,499</td>
</tr>
<tr>
<td>Mobile</td>
<td>509,177</td>
<td>582,264</td>
</tr>
<tr>
<td>Georgia</td>
<td>196,344</td>
<td>122,251</td>
</tr>
<tr>
<td>South Carolina</td>
<td>376,301</td>
<td>409,431</td>
</tr>
<tr>
<td>North Carolina</td>
<td>24,245</td>
<td>23,599</td>
</tr>
<tr>
<td>Virginia</td>
<td>25,788</td>
<td>24,705</td>
</tr>
<tr>
<td>Texas</td>
<td>38,832</td>
<td>145,296</td>
</tr>
<tr>
<td>Tennessee, &amp;c.</td>
<td>9,624</td>
<td>4,784</td>
</tr>
<tr>
<td>Total crop</td>
<td>3,118,942</td>
<td>2,909,519</td>
</tr>
</tbody>
</table>

Total crop of 1838, as above - 3,118,922
Crop of last year - 2,669,519
Crop of year before - 3,257,545

Increase from last year - 174,443
Decrease from year before - 413,883

Export to Foreign Ports in 1857-8.

<table>
<thead>
<tr>
<th>Years</th>
<th>Great Britain</th>
<th>France</th>
<th>North of Europe</th>
<th>Other Foreign Countries</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Orleans</td>
<td>1,016,716</td>
<td>473,564</td>
<td>1,490,280</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile</td>
<td>925,464</td>
<td>121,566</td>
<td>1,047,030</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td>203,856</td>
<td>164,464</td>
<td>368,320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savannah</td>
<td>149,446</td>
<td>15,826</td>
<td>165,272</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charleston</td>
<td>192,285</td>
<td>105,163</td>
<td>297,448</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Carolina</td>
<td>33,933</td>
<td>4,056</td>
<td>38,349</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltimore</td>
<td>16,144</td>
<td>161</td>
<td>16,305</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philadelphia</td>
<td>595</td>
<td>104</td>
<td>699</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York</td>
<td>116,542</td>
<td>37,391</td>
<td>153,933</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston</td>
<td>114,110</td>
<td>1,059</td>
<td>115,169</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total - 1,509,905
Total last year - 1,425,750
Increase - 84,155

Quantity consumed by, and in the hands of, Manufa.

<table>
<thead>
<tr>
<th>Years</th>
<th>Great Britain</th>
<th>France</th>
<th>North of Europe</th>
<th>Other Foreign Countries</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Orleans</td>
<td>3,113,362</td>
<td>1,397,610</td>
<td>2,590,057</td>
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</tr>
<tr>
<td>Mobile</td>
<td>929,926</td>
<td>178,370</td>
<td>1,108,296</td>
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<tr>
<td>Texas</td>
<td>203,856</td>
<td>164,464</td>
<td>368,320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savannah</td>
<td>149,446</td>
<td>15,826</td>
<td>165,272</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charleston</td>
<td>192,285</td>
<td>105,163</td>
<td>297,448</td>
<td></td>
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</tr>
<tr>
<td>North Carolina</td>
<td>33,933</td>
<td>4,056</td>
<td>38,349</td>
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<tr>
<td>Baltimore</td>
<td>16,144</td>
<td>161</td>
<td>16,305</td>
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<tr>
<td>Philadelphia</td>
<td>595</td>
<td>104</td>
<td>699</td>
<td></td>
<td></td>
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<tr>
<td>New York</td>
<td>116,542</td>
<td>37,391</td>
<td>153,933</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston</td>
<td>114,110</td>
<td>1,059</td>
<td>115,169</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total - 3,118,942
Total last year - 2,909,519
Increase - 289,423
CURCUMA ANGUSTIFOLIA.

Stock in Ports, and Price of "Middling" New Orleans, at the Close of each Year.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1840</td>
<td>300,000</td>
<td>22,700</td>
<td>95,500</td>
<td>14,800</td>
<td>22,000</td>
<td>300,000</td>
<td>19</td>
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<tr>
<td>1841</td>
<td>250,000</td>
<td>45,100</td>
<td>157,000</td>
<td>24,700</td>
<td>31,400</td>
<td>300,000</td>
<td>24</td>
<td>55</td>
</tr>
<tr>
<td>1842</td>
<td>288,000</td>
<td>65,700</td>
<td>172,900</td>
<td>20,200</td>
<td>22,200</td>
<td>351,400</td>
<td>25</td>
<td>45</td>
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<tr>
<td>1843</td>
<td>458,200</td>
<td>85,200</td>
<td>259,200</td>
<td>27,170</td>
<td>26,300</td>
<td>453,200</td>
<td>29</td>
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<tr>
<td>1844</td>
<td>544,900</td>
<td>67,200</td>
<td>299,200</td>
<td>15,000</td>
<td>41,400</td>
<td>583,500</td>
<td>33</td>
<td>45</td>
</tr>
<tr>
<td>1845</td>
<td>693,100</td>
<td>52,300</td>
<td>241,000</td>
<td>6,100</td>
<td>67,900</td>
<td>815,300</td>
<td>35</td>
<td>33</td>
</tr>
<tr>
<td>1846</td>
<td>582,600</td>
<td>23,700</td>
<td>174,600</td>
<td>4,500</td>
<td>57,400</td>
<td>764,100</td>
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<tr>
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<td>282,200</td>
<td>59,300</td>
<td>125,100</td>
<td>2,200</td>
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<td>409,600</td>
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<td>137,200</td>
<td>2,600</td>
<td>46,300</td>
<td>429,600</td>
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<tr>
<td>1849</td>
<td>316,400</td>
<td>85,200</td>
<td>107,000</td>
<td>2,000</td>
<td>38,000</td>
<td>509,400</td>
<td>18</td>
<td>57</td>
</tr>
<tr>
<td>1850</td>
<td>278,000</td>
<td>60,700</td>
<td>118,400</td>
<td>1,800</td>
<td>35,100</td>
<td>492,500</td>
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<td>57</td>
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<tr>
<td>1851</td>
<td>345,500</td>
<td>49,300</td>
<td>142,000</td>
<td>1,300</td>
<td>25,900</td>
<td>524,800</td>
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<td>77</td>
</tr>
<tr>
<td>1852</td>
<td>360,700</td>
<td>54,000</td>
<td>138,100</td>
<td>5,500</td>
<td>108,200</td>
<td>638,400</td>
<td>18</td>
<td>52</td>
</tr>
<tr>
<td>1853</td>
<td>385,900</td>
<td>45,900</td>
<td>270,600</td>
<td>4,000</td>
<td>38,300</td>
<td>557,500</td>
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<td>33</td>
</tr>
<tr>
<td>1854</td>
<td>314,900</td>
<td>47,300</td>
<td>244,000</td>
<td>4,000</td>
<td>50,000</td>
<td>525,200</td>
<td>17</td>
<td>55</td>
</tr>
<tr>
<td>1855</td>
<td>280,900</td>
<td>63,100</td>
<td>193,100</td>
<td>5,500</td>
<td>69,000</td>
<td>489,000</td>
<td>12</td>
<td>52</td>
</tr>
<tr>
<td>1856</td>
<td>175,190</td>
<td>21,700</td>
<td>89,400</td>
<td>700</td>
<td>27,170</td>
<td>372,400</td>
<td>8</td>
<td>72</td>
</tr>
<tr>
<td>1857</td>
<td>302,430</td>
<td>59,700</td>
<td>191,200</td>
<td>5,900</td>
<td>17,500</td>
<td>445,500</td>
<td>12</td>
<td>56</td>
</tr>
</tbody>
</table>

Cryolite. The mineral from which the metal Aluminium is obtained with the greatest facility. See Aluminium.

It derives its name from cryo, cold, from the circumstance of its being fusible in the flame of a candle. Its composition is—aluminium 1320; sodium 328; fluorine 54.2.

It was discovered at Arkstord, in West Greenland, by Gieszécke, associated in gnosis with galena, pyrites, and spathic iron. It is now obtained in large quantities.

Crystal. A crystal is a body which has assumed a certain geometric form. It is produced by nature, and may be obtained by art.

The ancients believed quartz to be water converted into a solid by intense cold, and hence they called it mineral crystal, from ουρυσταλλος, cold. This belief still lingers, many persons thinking that rock crystal is, in fact, congealed water. The term crystal is now applied to all solid bodies which assume certain regular forms. A crystal is any solid bounded by plane surfaces symmetrically arranged. Each mineral has its own mode of crystallization, by which it may be distinguished, and also its own peculiarity of internal structure.

We may have a mineral in a considerable variety of external forms, as pyrites, in cubes, octahedrons, dodecahedrons, &c.; but these are all resolvable into a single simple type—the cube. Thus galena, whatever external form it may assume, has an internal cubic structure. Fluor spar, usually occurring in cubic forms, may be cleaved into a regular octahedron. A little reflection will enable the student to see that nature in her simple arrangements maintains an unvarying internal type, upon which she builds up her varying and beautiful geometric forms. There are certain imaginary lines which are called the axes of the crystal: these may be

Rectangular and equal, as in the cube.

Rectangular and one unequal, as in the right rectangular prism.

The three axes unequal, vertical inclined to one of the lateral, at right angles to the other, two lateral at right angles with one another, as in the oblique rhombic prism.

The three axes unequal and all the intersections oblique, as in the oblique rectangular prism.

Three equal lateral axes intersecting at angles of 60° and a vertical axis of varying length at right angles with the lateral, as in the hexagonal prism.

Upon these simple arrangements of the axial lines all the crystalline forms depend, the particles of matter arranging themselves around these axes according to some law of polarity which has not yet been developed.

Curarine. An alkaloid existing in a black resinous matter called curarti, used by the American Indians for poisoning their arrows. It is singular that while the curarti poison is absolutely fatal when introduced, even in small doses, into a wound, it is inert when swallowed. Its composition is unknown, but it appears to be produced from one of the Strophanthus.—C. G. W.

Curcuma Angustifolia. The narrow leaved Turmeric. (East Indian Arrow Root). This plant is found in the forests, extending from the banks of the Loma to Nagpore. At Bhagnpor the root is dug up and rubbed on a stone or bed in a mortar, and afterwards rubbed in water with the hand and strained through a cloth; the fluid having subsided, the water is poured off, and the tinct (feuila) dried for use. The East Indian

—D. M.
CURLING STONE.

Arrow root is a fine white powder, readily distinguishable, both by the eye and the touch, from West Indian arrow root. To the eye it somewhat resembles a finely-powdered salt, (as bicarbonate of soda or Rochelle salt.) When pinched or pressed by the fingers, it wants the firmness so characteristic of West Indian arrow root, and it does not crepitate to the same extent when rubbed between the fingers.—*Pepira.*

At Travancore this starch forms a large portion of the diet of the inhabitants.

CURLING STONE. A stone used in Scotland in playing the national game of curling, which is practised upon the ice during the winter. The stone is made of a hydrated salt closely allied to the mineral asbestos, with small grains of quartz, and very minute particles of hornblende.—*Bristow.*

CYANATES. The combinations of the various bases with cyanic acid, (CNHNO.) The cyanate of potash, CNKO₂, is employed for the preparation of artificial ivory. There are two modes of preparing cyanate of potash, both of which yield a good product. The first is that of Clemm, the second of Liebig. 1. 8 parts of ferrocyanide of potassium and 3 parts of carbonate of potash are intimately mixed and fused, care being taken not to urge the heat too much. The fluid mass is allowed to fall somewhat in temperature, but not to such an extent as to solidify; 15 parts of red lead are then added by small portions. The crucible is now to be reheated with stirring, then removed, and the contents poured on to a clean iron plate. 2. The cyanide of potassium of commerce (prepared by the method described in the article under that head) is to be melted in an iron crucible or ladle, and 3 1/2 parts of dry litharge in fine powder are to be added with constant stirring. When the lead has all collected at the bottom, the whole is poured on to an iron plate. The mass obtained by either of the above processes is to be reduced to powder, and boiled with repeated quantities of alcohol, until no more cyanate is extracted. This may be known when the alcohol filtered from the residue no longer yields crystals of cyanate in cooling.

—C. G. W.

CYANIDES. The combinations of cyanogen with metals or other bodies. It has been remarked in the article HYDROCYANIC ACID that cyanogen, CN, is a compound salt radical, analogous to the halogen chlorine, iodine, and bromine. Like the latter it unites with water and the intervention of oxygen, and with the formation of the hydrocyanic, hydroiodic, and hydrobromic acids. The cyanides are both an important and interesting class of salts. The most important is the cyanide of potassium. The latter is formed under a great variety of circumstances, especially where carbonate of potash is heated in contact with carbonaceous matters. The nitrogen to form the cyanide in the greater number of instances is principally, and in a few entirely, derived from the atmosphere. Many chemists have experimented on this subject, and the results are by no means in harmony; but thus much is certain, that success or failure depends solely upon the circumstances under which the experiments are conducted. It has been shown that, when carbonate of potash mixed with charcoal prepared from sugar (see Carbon) is exposed to a very high temperature in a current of nitrogen gas, the potash in the carburet is, at times, absolutely converted into cyanide, not a trace of carbonate acid remaining. Experiments of this class, when made with animal charcoal or coal, are less conclusive because those matters contain nitrogen. But even then the amount of cyanogen found is out of proportion to the quantity of nitrogen in the coal or other carbonaceous matters. In fact it would seem that the presence of a certain quantity of nitrogen in the coal, &c., exercises a predisposing tendency on the nitrogen of the air so as to induce its combination with carbon with greater facility than would be the case if pure carbon were employed. Cyanide of potassium has been found on more than one occasion oozing from apertures in iron-smelting furnaces. In fact it is produced in such abundance at one furnace in Styria as to send into the market for sale to electro-platers. Cyanide of potassium is largely prepared for the use of electro-platers and gilders. The proportions of the materials used are those of Liebig, who first made known the process. The modes of manipulation, however, differ in the details in all laboratories. The following method can be recommended from the experience of the author of this article as giving a white and good product. It can, moreover, be worked on a very large scale. The ferrocyanide of potassium and salt of tartar are to be separately dried, pulverized, and sifted through coarse sieves. The salt of tartar must be free from sulphates. To 8 parts of dry ferrocyanide of potassium 3 of dry salt of tartar are to be added, and the two are to be incorporated by sifting. A large and strong iron pot is then to be suspended by a chain from a crane, in such a position that it can be lowered into the furnace and raised with ease; there must also be an arrangement to enable the pot to be arrested at any desired height. The pot being heated to redness, the mixture is to be thrown in by small portions until the vessel is half full; the heat being allowed to rise gradually until the whole flows pretty quietly. During the fusion the contents are to be stirred with a clean iron rod to promote the aggregation of the spongy sediment. As soon as the rod, on being dipped into the fused mass and removed, brings with it a pure, white, porcelain-like product, the operation may be regarded as terminated, and
the pot is to be raised from the fire by means of the crane and sling in a slightly inclined position. One of the operators now holds a large clean iron ladle under the edge of the pot, while another elevates the latter with the aid of tongs, so that the ladle becomes filled. The contents of the first ladle are then poured off into another held by the assistant who tilted the pot. The latter then pours the contents of his ladle into a large, shallow, and brilliantly-clean brass basin standing in another containing a little water so as to cool the fused cyanide rapidly. Extreme care must be taken to prevent even the smallest drop of water from finding its way into the brass vessel, because on the hot cyanide coming in contact with it an explosion would occur, scattering it in every direction, to the great danger of the persons in the vicinity. The two ladles are to be kept very hot, by being held over the fire until wanted, in order to prevent the cyanide from chilling until it is poured into the brass basin. The latter should be about 18 inches in diameter and 12 deep. It should be quite flat-bottomed. The object of so many pourings off is to prevent any of the sediment from finding its way into the product, and thus causing black specks in it. The pot, on being emptied as far as convenient, is to have the sediment removed and a fresh charge inserted. As soon as the coke of cyanide is cool, it is to be broken up into moderate-sized pieces and placed in dry and well-closed jars.

The cyanide of potassium possesses great points of interest for the technical and theoretical chemist. It is the salt from which an immense number of compounds of importance may be obtained. Very large quantities are made for the purpose of preparing the auro- and argento-cyanides of potassium for the electro-platers and gilders.

Auro-cyanide of potassium is capable of being formed in several ways. The following are convenient processes. The selection of a mode of preparing it will depend upon the circumstances under which the operation is situated. 1. By the battery. This process is perhaps the most generally convenient and economical for the electro-gilder. A bath is prepared by dissolving the best commercial cyanide of potassium in a warmed or filtered or distilled water. The best salt is that sold under the name of "gold cyanide." A Daniel's battery of moderate size being charged, two plates of gold are attached to wires and connected with it. The larger, which is to be dissolved, is attached to the positive, and the smaller, which need be but the size of a flattened wire, to the negative pole. The action of the battery is kept up until the desired amount is dissolved. It is easy to remove the plate used, dry and weigh it at intervals so as to know the proper time to stop the operation. 2. Toxide of gold (prepared with magnesia) is to be dissolved in a solution of cyanide of potassium.

Argento-cyanide of potassium.—This solution is easily prepared for the electro-plater by the following process: Metallic silver is dissolved in nitric acid and the solution evaporated to dryness. The residue is dissolved in distilled water and filtered. To the solution cyanide of potassium, dissolved in distilled water, is added, as long as precipitation takes place, but no longer. The precipitate is filtered off on calico strainers, and well washed with distilled water. It is then to be dissolved in solution of cyanide of potassium and diluted to the desired strength. The solution is frequently dark-colored at first, but it becomes colorless in a few hours, and should then be filtered from a small black precipitate which will be obtained. Many operators neglect the filtration and washing of the precipitated cyanide of silver, and merely continue the addition of the solution of cyanide of potassium to the nitrate of silver until the precipitate at first formed is redissolved. The first method is however to be preferred. Some, instead of precipitating with cyanide of potassium, do so with solution of common salt, and then, after washing off the precipitated chloride of silver, dissolve it in cyanide of potassium. Argento-cyanide of potassium can also be prepared with the battery by the process mentioned under auro-cyanide of potassium; this method is so convenient where the proper apparatus is at hand, that few professional electro-platers would use any other method. Daguerreotype artists who silver their plates, or rather, re-silver them, would find the battery process too cumbersome, and should, therefore, use a solution of argento-cyanide of potassium prepared by the first method.

In order to suspend Daguerreotype plates in the bath, the little contrivance figured in the margin, fig. 2116, will be found most convenient. It merely consists of pieces of copper wire twisted together and formed into a grasped at the lower end. It acts like a spring, and holds the plate so firmly that there is no fear of its falling out, even if the apparatus be subjected to severe vibration.—C. G. W.

CYANIDE OF POTASSIUM. See Cyanides. CYANOGEN, C7N. A compound salt radical, analogous in its character to chlorine and the other halogens. It was the first body discovered, the character of a compound radical, and the investigations made upon it and its derivations have thrown more light upon the constitution and proper mode of classifying organic substances than
any other researches whatever. In consequence of its acting in all its compounds as if it were a simple body or element, chemists generally have acquired the habit of designating it by the symbol Cy. Like the haloids it combines with hydrogen to form an acid, and with metals, without the necessity for the presence of oxygen. For a few illustrations of its analogies with chlorine, &c., see Hydrocyanic Acid. In the article Cyanides several of the conditions under which it is formed have also been pointed out. The modern French chemists of the school of Gerhardt very justly regard cyanogen in the light of a double molecule, thus, Cy Cy, or C=N. The reason of this is because most of the phenomena of organic chemistry are more easily explained by the use of four-volume formulae than any others. This latter mode of condensation has been shown by M. Wortz, in his admirable work on the compound radicals, to undoubtedly exist in the case of radicals belonging to the strict hydrogen type, not as ethyle and its homologues; and numerous theoretical and experimental results are in favor of the supposition that all radicals in the free state are binary groups.

If we assume the truth of the above hypothesis, we shall regard cyanogen in the free state as a cyanide of cyanogen, analogous to hydrocyanic acid, which is a cyanide of hydrogen.

Cyanogen may very conveniently be prepared by heating cyanide of mercury in a retort of hard glass. A considerable quantity of the gas is given off, but a portion remains behind in the state of parcyanogen. The latter substance is a black matter, the constitution of which is by no means understood. It has, however, the same composition in the hundred parts as cyanogen itself, and is therefore isomeric with it.

Cyanogen is a colorless combustible gas with a sharp odor. Its density is 1.81. It will burn for two hours 1,80. If cooled to a temperature of between —13° and —22° F., it liquefies into a transparent, colorless, and very mobile liquid having a specific gravity of 0.896. A little below 22° the fluid congeals to a mass resembling ice. The flame of cyanogen is of a pale purple or peach blossom color.

Some of the properties of cyanogen are very remarkable, and quite distinct from those of the true halogens. For instance, it combines directly with aniline to produce a body having basic properties. The latter is called cyaniline, and is formed by the coalescence of two molecules of cyanogen with two of aniline, the resulting formula being, consequently, C=N-H=N.

There are a variety of singular compounds produced by the action of cyanogen and its halogen compounds upon aniline; they have been studied with remarkable skill by Hofmann.—C. G. W.

CYMOPHANE. A variety of Chrysoberyl, which exhibits a peculiar milky or opalescent appearance. When cut en cabochon, it shows a white floating band of light, and is much prized as a ring stone.—H. W. B.

DAGUERREOTYPE. The progressive advance of this branch of the photographic art, though of great interest, cannot be dwelt on in this place. Those who are interested in the inquiry, will find the information fully detailed in Hunt's Manual of Photography, 6th edition, 1857. It will be sufficient in this work to deal with the more important improvements which have become generally adopted. The first advance of real importance was made by Mr. Towson, of Devonport, who has since that time distinguished himself by the introduction of his system of Great Circle Sailing. Mr. Towson suggested the use of enlarged lenses, and by acting with such, Dr. Draper, of New York, was the first to procure a portrait from the life. Still this was a tedious process, but in 1840 Mr. Goddard proposed the use of bromine of iodine, by which infinitely increased sensibility was obtained. From that time the Daguerreotype was generally employed for portraiture, until the facilities of the collodion process drove it from the field.

The improved manipulation now resolves itself into carefully polishing the silver plate, and the application finally of the highest polish by the use of a buffer, the best form being that employed by M. Claudet.

In a box on a roller, to which there is a handle, fig. 315, is placed a long piece of drab-
colored velvet, which can be drawn out and extended by means of a second roller upon a perfectly flat table. The first foot or two, for example, is drawn out; the plate which has already received its preliminary polishing is placed face downwards, and being pressed close with the fingers a rapid circular motion is given to it, and in a few minutes it receives its highest lustre. As the velvet becomes blackened by use, it is rolled off, the portion remaining in the box always perfectly clean and ready for use.

The iodizing process follows: and for this purpose a box similar to that represented will be found to be very convenient, (fig. 215.) This iodizing apparatus consists of a square box with a closely-fitting cover 6, false sides are placed at an angle with this box, a cup D at the bottom contains the iodine, which is covered with a thin gauze screen. J J, c is a cover which confines the iodine when it is not required for the plate; this dividing the box into two parts, H H, and K K, the former being always full of iodine vapor. When it is desired to iodize a plate, the cover c is removed, the silver plate is placed at k, and the cover a closed.

The plate is thus placed in the iodine box until it acquires a fine straw yellow color. In another box is placed either bromine or some one of the many accelerating fluids. If bromine, or any bromide is employed, the plate should remain until it becomes of a rose color. As a general rule, if the yellow color produced by iodine be pale, the red should be pale also; if deep, the red must incline to violet. The proper time for exposing a plate to any of these chemical substances which are destined to produce the sensitive film, must vary with the temperature, and it can only be determined by experience. The sensitive plate is now removed to the camera obscura, for a description of which see P h o t o g r a p h y. It is scarcely necessary to say, that the plate must be preserved in perfect darkness until exposed to the image. A few seconds when the plate is properly prepared will be found amply sufficient to produce the best effect.

The impression must be developed in the mercury box (fig. 214) in the manner described by Daguerre. This mercurial box consists of a box mounted on legs, having a close-fitting cover a, and an iron bottom in which is placed the mercury c, and a small thermometer r to indicate the proper temperature. a is a piece of glass let into the side of the box through which the Daguerreotype plate, fixed in the frame n, can be seen. d is a spirit lamp, and i the platform on which it stands. The subject is eventually fixed by the use of hypo-sulphite of soda, which removes the bromo-iodide of silver and leaves a picture produced by the contrast between a combination of the silver and mercury, and the surface of the unchanged, polished silver.

The application of chloride of gold to the finished picture was introduced by M. Fizeau.

Chloride of gold applied to the picture has the effect of fixing and enlivening the tints. A small grate being fixed by a clamp to the edge of a table, the plate is laid upon it with the image uppermost, and overspread evenly with solution of chloride of gold, by means of a fine broad camel hair brush, without letting any drop over the edge. A spirit lamp is now brought under the plate, and moved to and fro till a number of small steam bubbles appear upon the image. The spirit lamp must be immediately withdrawn. The remainder of the chloride solution must be poured back into the pot, to be used on another occasion. It is lastly to be washed and examined. This operation has been repeated three or four times with the happiest effect of giving fixity and force to the picture. It may then be wiped with cotton without injury. The process of coloring these pictures is a purely artificial one, which, while it destroys the beauty of the photograph, does not in any way improve it as a picture.

Daguerreotype Engraving.—Several processes for etching the Daguerreotype plate were
introduced with more or less success. Professor Grove produced a few good engravings by the action of voltaic electricity. Berard and B醚erkerel were also enabled to produce some promising results by a similar process. The following process by M. Claudet was carried out to some extent with every prospect of success.

The new art, patented by M. A. F. J. Claudet on the 21st of November, 1843, was established on the following facts: A mixed acid, consisting of water, nitric acid, nitrate of potash, and common salt in certain proportions, being poured upon a Daguerreotype picture, attacks the pure silver, forming a chloride of that metal, but does not affect the white parts, which are produced by the mercury of the picture. This action does not last long. Water of ammonia, containing a little chloride of silver in solution, dissolves the rest of that chloride, which is then washed away, leaving the washed metal to be again attacked, especially with the aid of heat. The metallic surface should have been perfectly purified by means of alcohol and caustic potash. For the rest of the ingenious but complex details, see "Newton's Journal," C. S. vol. xxx, p. 112.—See ACTINISM, COLLODION PHOTOGRAPHY.

DAMAR GUM, or DAMMARA RESIN. A pale yellow resin, somewhat resembling copal, and used like it in the manufacture of varnishes. Dammara resin is said to be derived from the "Pinus dammara alba" of India. A Dammara resin is also imported from New Zealand, which is the product of the "Dammara Australis." Under the name of Cowdie resin, it is said to be used extensively as a varnish in America. "Damar is easily dissolved in oil of turpentine, and when carefully selected is almost colorless; it makes a softer varnish than mastic; the two combined, however, form an almost colorless varnish, moderately hard and flexible, and well suited for maps and similar purposes."—Holtzapfell.

DAMASCUS BLADES. The characteristics ascribed to the real Damascus blades are extraordinary keenness of edge, great flexibility of substance, a singular grain of fleckness always observable on the surface, and a peculiar musky odor given out by any friction of the blade, either by bending or otherwise. The author of "Manufactures in Metals" remarks:

"A gentleman who purchased one of these blades in the East Indies for a thousand piasters, remarked to the writer of this volume that, although the instrument was very flexible, and bore a very keen edge, it could not with safety be bent to more than 45° from the straight shape, and it was not nearly so sharp as a razor, yet, wielded by a skilful hand, it would cut through a thick roll of sail-cloth without any apparent difficulty; a feat which could not be performed with an ordinary sword, nor, it should be observed, by the sabre itself in an ordinary hand, though the swordsman who tried it could, it appears, do nearly the same thing with a good European blade."

Emerson, in his letters from the Jægian, says: "I have seen some blades (scimitars) which were valued at 200 or 300 dollars; many are said to be worth triple that sum, and all under the name of Damascus, though it is by no means likely that they have been manufactured there. The twisting and intertwisting of the fibres of the metal are considered as the tests of excellence, but I have never seen any possessed of the perfume said to be incorporated with the steel in the real Damascus blade."

The production and use of damask steel have received much attention from the late General Anossof, of the Corps of Engineers of the Imperial Russian army, and Master of the Fabric of Arms at Zlatoust, in Siberia. His researches and successful practice have become matters of history.

Steel helmets and cuirasses were formed of cast and damascened steel, intermixed with pure iron, a mixture supposed to combine toughness and hardness in the greatest possible degree.

At different periods these works have been visited, separately, by two English travellers, Major Abbott of the Bengal Artillery, and Mr. Atkinson, who have recorded the results of observation, experiment, and conversational intercourse, and they state severally their conviction that the damask steel produced by Anossof rivalled in beauty and excellence any works they had ever seen in other lands. They accord to Anossof the honor of being the reviver of the art of making damask steel in Europe, while they declare the Russian natural damask steel is not approached by the fabrics of any eastern nation now existing.

The Siberian swords and daggers were compared and tried with the choicest specimens, and found equal to the blades of Damascus and the sabers of Khorsan; and while these valued articles might have been selected from numbers manufactured by chances of skill and material, Anossof united chemical analyses of ores and steel, and records of observations on progressive stages, to give a true history of the means to explain and insure success.

DAMASCUS GUN-BARRELS. See Fire-Arms, vol. i.

DECKLE, name given by the paper maker to a thin frame of wood fitting on the shallow mould in which the paper pulp is placed.
DECOMPOSITION. The separation of bodies from each other. The methods employed are almost innumerable, and usually depend on the special reactions of the matters under examination. We shall consider a few of the most striking cases in both the grand divisions of the science, viz., inorganic and organic chemistry. In each instance we shall, for the sake of convenience, subdivide into the three classes of acids, alkalies, and neutral bodies. Previous, however, to this, we must glance at some of the reactions of which chemists avail themselves in separating the elements. The decomposition of ordinary metallic salts, with the view of making a qualitative analysis of a more or less complex mixture, is a problem, in general, of extreme simplicity, and directions for the purpose are to be found in all the numerous works on qualitative analysis. The principle on which the modern methods of qualitative analysis are founded, is the separation of the first place into large groups by certain reagents, and then by means of others, to subdivide into smaller groups, in which the individual metals can be determined by special tests. For the sake of simplicity, we shall only consider the more commonly occurring metals. The general reagents, by which the first subdivision is effected, are hydrochloric acid, sulphuric acid, sulphide of ammonia, carbonate of ammonia mixed with chloride of ammonium, and finally phosphate of soda. The substance in solution is treated with hydrochloric acid, by which mercury, silver, and lead are removed. The mercury will only be perfectly removed if it exists entirely in the state of a sublimate. Lead is only partially precipitated, and will be subsequently found in the next group. The precipitate by hydrochloric acid is to be boiled with water, which will remove the chloride of lead, and leave the chlorides of mercury and silver. The latter may be separated by means of ammonia, which will sublime the chloride of silver and convert the mercury into a black powder, in which the metal can be detected by special tests. The fluid filtered from the precipitate by hydrochloric acid is to have a stream of hydrosulphuric acid gas passed through it for a considerable time, or until no more precipitation occurs. By this means antimony, arsenic, tin, cadmium, gold, mercury, silver, lead, bismuth, and copper are thrown down, and must be separated from each other by special processes. The filtrate from the precipitate by hydrosulphuric acid is to have ammonia added in slight excess, and then a solution of sulphide of ammonium as long as any precipitation takes place. By this means nickle, cobalt, iron, manganese, zinc, alumina, and chromium are thrown down; also baryta, strontia, and lime, if they happen to be in combination with phosphoric, oxalic, or boracic acids, or if united to fluorine. From the filtrate, carbonate of ammonia mixed with chloride of ammonium, precipitates baryta, strontia, and lime. The filtrate from the last precipitate can only contain magnesia, or the alkalies. The above brief description of the mode of dividing the metals into groups will be sufficient to give an idea of the processes employed for decomposing complex mixtures into simple ones.

Inorganic acids are usually removed from metals by converting the latter into an insoluble compound, while the acid remains in solution either in the free state or combined with a base. As not to mask the reactions of the acid with reagents which is often done in the laboratory by boiling the metallic salt with an alkaline carbonate. The metals are, consequently, either converted into oxides or carbonates insoluble in water, while the acid unites with the alkali to form a soluble salt capable of being obtained by filtration in such a condition as to permit the nature of the acid to be made known by means of appropriate tests. It is usually necessary to neutralize the solution carefully before testing for the acid.

It is seldom necessary in researches to reduce inorganic alkalies to their elements, their constitution being usually ascertained by converting their constituents into new forms capable of being weighed or measured with accuracy. If, for instance, it was necessary to ascertain the constitution of sulphuric acid, it would be sufficient to determine the quantity of baryta contained in the sulphate. On the other hand, acids susceptible of assuming, when pure, the gaseous condition, may have their constitution determined by decomposing a known volume with a substance capable of combining with one ingredient and liberating the other in the gaseous state. Thus hydrosulphuric acid may be analyzed by heating it with potassium, which will remove the sulphur and liberate the hydrogen.

In decomposing inorganic alkalies with the view of separating the metals contained in them, we usually have to avail ourselves of very powerful affinities. This arises from the fact, that the substances in question are, generally, produced by the union of a metal with oxygen, the metal having so strong a tendency to combine with that element, that mere exposure to the air is sufficient to determine their union into a compound of great stability. In order, therefore, to decompose the alkalies of this class, it is necessary to find some substance having a powerful tendency to combine with oxygen under certain conditions. Now it has been found that carbon, if raised to an exceedingly high temperature, and employed in great excess, is capable of removing the oxygen, even from such bodies as potassium and sodium, the affinity of which for oxygen is very great.

Inorganic neutral bodies are generally decomposed either by the ordinary processes of
DECOMPOSITION.

analysis, or, where the neutrality arises from the substance under examination being a compound of an acid and a base, by separating the two by treatment with a reagent capable of combining with one to the exclusion of the other. This is a process frequently available in quantitative analysis. As an illustration we may take the decomposition of the carbonates by a saline acid in an apparatus which permits the carbonic acid set free to be accurately estimated by weighing. (See Carbonates.) Another instance of the decomposition of a neutral body, by treating it with a substance capable of combining with one of the constituents and separating the other in a free state, is the decomposition of sulphate of potash by baryta. If a solution of the salt be boiled with excess of solution of baryta, sulphate of baryta is produced and caustic potash set free. The excess of baryta is removed by boiling in the air until the whole of the latter base is converted into the insoluble carbonate. A precisely analogous process is the ordinary mode of preparing caustic potash by boiling its carbonate with quicklime.

Neutral bodies are frequently, however, so constituted that the neutrality does not arise from the circumstance of an acid being saturated with a base, but from the energies of the two elements being, to some extent, satisfied by the fact of their being in combination. Thus, water is a neutral substance, nevertheless it may be decomposed by a variety of processes, several of which are susceptible of quantitative precision. In the first place, it may be decomposed by passing steam over a metal capable of uniting with its oxygen with liberation of the hydrogen. It may also be electrolyzed and the two gases separately obtained.

Organic or inorganic neutral salts may, at times, be completely and simply decomposed by means of the battery. Not only are the various processes in electro-metallurgy founded on this principle, but it has even been practically applied to the quantitative estimation of the metals in ores. The electrolysis of the neutral salt of the great series of organic acids of the general formula $\text{C}_n\text{H}_{2n}\text{O}_x$ has thrown great light on some previously obscure points in the radical theory.

The decompositions undergone by organic substances in contact with reagents are so manifold, that the limits of this work preclude the possibility of doing more than glancing at a few of the most general and interesting. Perhaps of all the modes of inducing the breaking up of more complex into simpler substances, the application of heat is the most remarkable for its power and the varied and opposite character of the substances produced. It has been shown that, as a decomposing agent, heat possesses no special function. From certain organic molecules all classes of substances are formed. Individual substances belonging to every chemical type are, therefore, found among products of destructive distillation.

Acids, alkalies, and neutral bodies of every kind are formed, and some of the most interesting and beautiful bodies known to chemists are found in the uninviting looking tar of coal. Let us illustrate this by a glance at a few of the coal-tar products. Among the acids are the oxyphonic, carboxic, and cresyllic. The alluobals represented are methylamine, ethylamine, propylamine, butylamine, and phenylamine, pyridine, picoline, lutidine, collidine, pyrrole, chloroform, urea, and amine. Among hydrocarbons, benzole, toluole, xylode, cumole, cyrene, propyle, butyl, amyle, caproyle, caproylene, cyanethylene, naphtaline, anthracene, chrysene, pyrene, &c., &c. This list, probably, does not include one-half of the substances produced from coal by the decomposing and recomposing influence of heat.

Mineral acids exercise a powerful decomposing influence on organic substances. Of these the nitric and sulphuric are the most commonly used. Nitric acid is especially active, owing to its twofold action. By virtue of its oxidizing tendencies, it breaks up great numbers of substances into more simple and less carburetted derivatives, and the hyponitric acid produced by the removal of one of the atoms of the oxygen of the acid frequently enters into the resulting compound, a substitution product being the final result. In the latter bodies produced in this manner the hyponitric acid (NO) generally replaces hydrogen, the original type remaining unaltered. The production of oxalic acid from sugar: succinic, lipid, adipic, pinelic, suberic, &c., acids from oily and fatty matters by the action of nitric acid, are examples of its oxidizing power; while the formation of nitrobenzole, and bodies of more or less analogous character, presents instances of the replacement of hydrogen by hyponitric acid.

Sulphuric acid owes its decomposing power to its extreme tendency to combine with water. Many of the less stable organic bodies are, by this means, absolutely broken up, so that the resulting products are of a character too indefinite to allow of the changes being expressed by an equation which shall render a true account of all the substances directly or indirectly formed. On the other hand, the action may be so controlled by the careful regulation of the temperature and strength of the acid that products may be eliminated which are themselves totally broken up and destroyed by an acid of greater strength. The production of grape sugar by the action of sulphuric acid on starch, or lignine, may be taken as an example. It not unfrequently happens, that the sulphuric acid unites with the substance acted on to form a conjugated compound. Benzole, and many other hy-
Chlorine and the other halogens are powerful decomposing agents, acting chiefly by virtue of their affinity for hydrogen. The principal effects produced by them are oxidation and sublimation. The oxidizing action of the halogens arises from the decomposition of water; the hydrogen combining with the chlorine, &c., to form an hydracid, and the free oxygen uniting with the other substances present.

The above sketch will sufficiently indicate some of the most usual methods by which the decomposition of organic and inorganic bodies is effected; but hundreds of other decomposing agencies are at the call of the chemist, when any phenomena involving the disruptions of compounds are to be investigated.—C. G. W.

DEODORIZERS. Bodies which have the power of depriving fetid and offensive effluvia of their odors. There appears to exist a general idea that these substances are, all of them, equally disinfectants. No greater mistake can be made than to suppose that because a preparation has the power of removing a disagreeable smell, that therefore it has removed all the elements of infection or disease. See Disinfector.

To disguise unpleasant odors, fumigation is employed, many of the fragrant gums are burnt, and fumigating pastilles employed. It is also a common practice to burn lavender and brown paper, but these merely overpower or disguise the smell; they do not in any way act upon the noxious effluvia.

DERRICK CRANE. The term Derrick is applied to a temporary crane, consisting of a spar supported by stays and guys, carrying a purchase for loading or unloading goods on shipboard. The Derrick crane is somewhat similar in its plan, the projecting iron beam or derrick of which can be raised or lowered to any desired angle.

DESICCATION. The act of drying.

Davison and Symington patented a process for drying or seasoning timber, by currents of heated air. Even after wood has been dried in the ordinary manner, it contains much moisture, which it is still necessary to remove. The patentees have given some curious results of this desiccating process:

Temperature of air 214°.

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<th>Violin wood.</th>
<th>Original weight.</th>
<th>120° after 6 hours.</th>
<th>120° after 10 hours.</th>
<th>150° after 20 hours.</th>
<th>180° after 30 hours.</th>
<th>220° after 38 hours.</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 pieces small and thin</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 pieces larger</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 pieces larger</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

| Oak | - | - | 1-54 | 1-76 | 1-71 | 1-50 | 1-56 | 1-51 | 18-1 |
| Red pine | - | - | 1-5 | 1-4 | 1-38 | 1-33 | 1-28 | 1-25 | 16-6 |
| Birch | - | - | 1-2 | 1-09 | 1-05 | 1-01 | 0-99 | 0-97 | 19-2 |
| Mahogany | - | - | 1-21 | 1-14 | 1-09 | 1-03 | 1-0 | 0-98 | 19-2 |

White wood, lime tree.

<table>
<thead>
<tr>
<th>Original weight.</th>
<th>170° after 6 hours.</th>
<th>Part 140° and part 212° after 15 hours.</th>
<th>After 24 hours.</th>
<th>After 34 hours.</th>
<th>After 34 hours.</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23-5</td>
<td>20-45</td>
<td>18-7</td>
<td>18-22</td>
<td>17-4</td>
<td>17-1</td>
</tr>
<tr>
<td>2</td>
<td>25-19</td>
<td>21-33</td>
<td>19-37</td>
<td>18-9</td>
<td>18-07</td>
<td>18-0</td>
</tr>
<tr>
<td>3</td>
<td>23-87</td>
<td>19-7</td>
<td>17-53</td>
<td>17-6</td>
<td>16-82</td>
<td>16-75</td>
</tr>
<tr>
<td>4</td>
<td>20-08</td>
<td>17-07</td>
<td>15-8</td>
<td>15-6</td>
<td>15-13</td>
<td>15-05</td>
</tr>
</tbody>
</table>

No. 3 exposed to the atmosphere for three weeks, weighed at the end of that time 17-8, or had taken in 4-2 per. cent of moisture.

* It will be observed, on referring to the last column of lime, that the wood, although kept in the chamber exposed to heated currents for 50 hours, weighed nothing less after the first 34 hours.—Walt-ter. One application of the desiccating process for timber is to expose it for some hours to the heated currents of air, and then, in its heated state, immerse it suddenly in any of the approved antidotes, cresote or coal-tar. The result is, that the air-vessels of the wood, if not entirely empty, contain air at so very high a temperature that a vacuum is instantly formed, and very pores is immediately charged with the cold antidote in which the wood is immersed.
DEXTRINE.

Feathers.—Feather beds, mattresses, blankets, and clothing are not only dried, but purified by this process. A feather bed of sixty pounds' weight, will have no less than 100,000 cubic feet of air passed through it; and at the same time beaters are made use of, for the purpose of removing the dust. Feathers treated in this manner have their bulk and elasticity so much increased, that a second tick is found almost invariably necessary to put the feathers into.

A practical proof of the extreme powers of currents of dry heated air was given in Syria, by exposing to them sixty suits of clothes, which had belonged to persons who died of the plague. These clothes were subjected to the process almost to, at a temperature of about 240°, and afterwards worn by sixty living persons, not one of whom ever gave the slightest symptoms of being in the slightest degree affected by the malady. (Whishaw.) The purification of feathers by this process is carried out in many large establishments. Coffee it has been proposed to dry by currents of heated air, and subsequently to roast it by the same process.

Thick card-board, used for ten-trays and paper mache, is now frequently dried by heated air. By the plan adopted at one establishment, previously to the introduction of Davison and Symington's method, it invariably occupied from eighteen to twenty hours to dry a room full of paper by a heating surface equal to 330 feet; whereas by the new method the same amount of work is accomplished in four hours, and with a heating surface of only 46 square feet, while one-seventh the area required by the former process.

Silk.—For the purpose of drying silk, it has been usual to heat the drying chambers by large cast-iron globular stoves; the heat obtained thus was equal to 120° F., but excessively distressing to any stranger entering these apartments.

In one arrangement 7,000 cubic feet per minute are admitted at the above temperature through small perforated iron plates, let into the stone floor. As many as 5,000 pieces of silk are sometimes suspended at one time; and are, when wet, contains about seven ounces of water, and as the operation of drying the whole occupies but one hour, it follows that about 130 gallons of water are evaporated in that time.

Yarns.—In Scotland and other places they now dry yarns by modified applications of this process; and it is indeed extensively used in bleaching establishments, in calcéo-printing, &c. See Transactions of the Society of Arts for 1847-8.

DEXTRINE. Starch Gum. There are three modes of obtaining this from starch, viz.: by torrefaction, by the action of dilute acids, and by the action of diastase. The impure dextrine obtained by roasting is termed roasted starch, or leicam. British gum is prepared by carefully roasting wheat starch, at a temperature of 300° Fahr. Another method of preparing dextrine consists in moistening 1,000 parts of potato starch with 300 parts of water, to which two parts of nitric acid have been added. The mixture is allowed to dry spontaneously, and is afterwards heated for two or three hours in a stove at 212° Fahr. Dextrine in many of its characters resembles ordinary gum, but it is distinguishable from it by its right-handed rotation of a ray of plane polarized light,—hence its name dextrine,—and by its yielding oxalic acid, but not mucic acid, when heated with nitric acid. Its chemical formula is C₃₂H₄₂O₁₈.

DIAMAGNETISM. As this term is becoming more generally used in our language, it appears necessary to give a definition of it, although it is not our purpose to enter on the consideration of any purely physical subject.

The term was introduced by Dr. Faraday to express those bodies which did not act as magnetic bodies do. If x and s represent the poles of a horse-shoe magnet, any bar of a magnetic character, as iron, cobalt, or nickel, hung up between them and free to move, will, by virtue of the attracting and repelling polar forces, place itself along the line joining the two poles a b, which is called the magnetic axis. If instead of a bar of iron we suspend in the same manner a rod of glass, of bismuth, or of silver, it will arrange itself equatorially, or across the line a b, as shown by the dotted line c d. All bodies in nature appear to exist in one of those two conditions. The prefix dia is used here in the same sense as in dia-meter. See De La Rive's Electricity, for a full explanation of all the diamagnetic phenomena.

DIAMOND. (Diament, Fr.; Diamant, Germ.) Experiment has determined that this beautiful gem is a peculiar (allotropic) condition of carbon. By burning the diamond in oxygen gas we produce carbousic acid; and by enclosing the gem in a mass of iron, and subjecting it to a strong heat, the metal is converted into steel, when the diamond has disappeared. It has been shown that we can, by the agency of the heat of the voltaic pile, convert the diamond into excellent coke, and into graphite; but although portions of coke are found to be sufficiently hard to cut glass, we have not yet succeeded in making diamonds from coke. Sir Humphry Davy noticed that the charcoal of one of the poles of Mr. Children's great voltaic battery was considerably hardened, and he regarded this as an
advance towards the production of that gem. Recently some experiments made by a French philosopher have advanced the discovery another step: one of the poles of a voltaic battery being charcoal and the other of platinum, it was found that the fine charcoal escaping from the carbon pole and depositing itself on the platinum pole was sufficiently hard to be used in the place of diamond dust for polishing gems. The formation of the diamond in nature is one of the problems which "our philosophy" has not yet enabled us to solve. Time is an element which enters largely into nature's works; she occupies a thousand, or even thousands of years, to produce a result, while man in his experiments is confined to a few days, or a few years at most.

The following remarks by Mr. Tennant cannot fail to be of interest, and, as pointing out the errors which have been frequently committed through ignorance, of great value.

"By attending to the forms of the crystal, we are quite sure that we shall not find the emerald, sapphire, zircon, or topaz, in the form of a cube, octahedron, tetrahedron, or rhomboic dodecahedron; nor the diamond, spinel, or garnet, in that of a six-sided prism, and so on with other gems. For want of a knowledge of the crystalline form of the diamond, a gentleman in California offered £200 for a small specimen of quartz. He knew nothing of the substance, except that it was a bright shining mineral, excessively hard, not to be scratched by the file, and which would scratch glass. Presuming that these qualities belonged only to the diamond, he conceived that he was offering a fair price for the gem; but the owner declined the offer. Had he known that the diamond was never found as a six-sided prism, terminated at each end by a six-sided pyramid, he would have been able to detect the fact that what he was offered £200 for, was really not worth more than half a crown."—Tennant's Lecture on Gems.

The accompanying forms may serve to guide those who are ignorant of crystallography.

The following technical terms are applied to the different faces of diamonds:

*Brilliant*: the upper sides and corners of the brilliant, lying between the edge of the table and the girdle.

*Collet*: the small horizontal plane or face, at the bottom of the brilliant.

*Crown*: the upper work of the rose, which all centres in the point at the top, and is bounded by the horizontal ribs.

*Facets*: small triangular faces, or planes, both in brilliants and roses. In brilliants there are two sorts, skew or skill-facets, and star-facets. Skill-facets are divided into upper and under. Upper skill-facets are wrought on the lower part of the bezil, and terminate in the girdle; under skill-facets are wrought on the pavilions, and terminate in the girdle; star-facets are wrought on the upper part of the bezil, and terminate in the table.

*Girdle*: the line which encompasses the stone parallel to the horizon; or, which determines the greatest horizontal expansion of the stone.

*Lazurite*: are common to brilliants and roses. In brilliants they are formed by the meeting of the skill and star-facets on the bezil. In roses, by the meeting of the facets in the horizontal ribs of the crown.

*Pavilions*: the under sides and corners of brilliants, lying between the girdle and the collet.

*Ribs*: the lines, or ridges, which distinguish the several parts of the work, both in brilliants and roses.

*Table*: the large horizontal plane, or face, at the top of the brilliant.

Fig. 218 represents a brilliant, and fig. 219 a rose-cut diamond.
DIAMOND CUTTING.

Triangles leave spaces between them which are likewise cut each into two facets. By this distribution the rose diamond is cut into 24 facets; the surface of the diamond being divided into two portions, of which the upper is called the crown, and that forming the contour beneath the former, is called *dentelle* (lace) by the French artists.

According to Mr. Jefferies, in his Treatise on Diamonds, the regular rose diamond is formed by inscribing a regular octagon in the centre of the table side of the stone, and bordering it by eight right-angled triangles, the bases of which correspond with the sides of the octagon; beyond these is a chain of 8 trapeziums, and another of 16 triangles. The collet side also consists of a minute central octagon, from every angle of which proceeds a ray to the edge of the girdle, forming the whole surface into 8 trapeziums, each of which is again subdivided by a salient angle (whose apex touches the girdle) into one irregular pentagon and two triangles.

To fashion a rough diamond into a brilliant, the first step is to modify the faces of the original octahedron, so that the plane formed by the junction of the two pyramids shall be an exact square, and the axis of the crystal precisely twice the length of one of the sides of the square. The octahedron being thus rectified, a section is to be made parallel to the common base or *girdle*, so as to cut off 5-eighths of the whole height from the upper pyramid, and 1-eighth from the lower one. The superior and larger plane thus produced is called the *table*, and the inferior and smaller one is called the *collet*; in this state it is termed a *complete square table diamond*. To convert it into a brilliant, two triangular facets are placed on each side of the table, thus changing from a square to an octagon; a lozenge-shaped facet is also placed at each of the four corners of the table, and another lozenge extending lengthwise along the whole of each side of the original square of the table, which, with two triangular facets set on the base of each lozenge, completes the whole number of facets on the table side of the diamond; viz., 8 lozenges, and 24 triangles. On the collet side are formed 4 irregular pentagons, alternating with as many irregular lozenges, inscribing from the collet as a centre, and bordered by 16 triangular facets adjoining the girdle. The brilliant being thus completed, is set with the table side uppermost, and the collet side implanted in the cavity made to receive the diamond. The brilliant is always three times as thick as the rose diamond. In France, the thickness of the brilliant is set off into two unequal portions; one-third is reserved for the upper part or table of the diamond, and the remaining two-thirds for the lower part or collet, (*culasse*.) The table has eight sides, and its edge forms are cut into facets, of which some are triangles and others lozenges. The collet is also cut into facets called *pavilions*. It is of consequence that the pavilions lie in the same order as the upper facets, and that they correspond to each other, so that the symmetry be perfect, for otherwise the play of the light would be false.

Although the rose diamond projects bright beams of light in more extensive proportion often than the brilliant, yet the latter shows an incomparably greater play, from the difference of its cutting. In executing this, there are formed 32 faces of different figures, and inclined at different angles all round the table, on the upper side of the stone. On the collet (*culasse*) 24 other faces are made round a small table, which converts the culasse into a truncated pyramid. These 24 facets, like the 32 above, are differently inclined, and present different figures. It is essential that the faces of the top and the bottom correspond to one another in sufficiently exact proportions to multiply the reflections and refractions, so as to produce the colors of the prismatic spectrum.

**DIAMOND CUTTING.** The following description, furnished to Mr. Tennant by Messrs. Garrard, of the cutting of the Koh-i-inoor, will fully explain the peculiar conditions of the process, and also show that there are some remarkable differences in the physical condition of the gem in its different planes. The letters refer to the cut of the Koh-i-inoor, article DIAMOND, fig. 220.

"In cutting diamonds from the rough, the process is so uncertain that the cutters think themselves fortunate in retaining one-half the original weight. The Koh-i-inoor, on its arrival in England, was merely surface-cut, no attempt having been made to produce the regular form of a brilliant, by which alone lustre is obtained. By reference to the figures, which are the exact size of the Koh-i-inoor, it will be clearly understood that it was necessary to remove a large portion of the stone in order to obtain the desired effect, by which means the apparent surface was increased rather than diminished, and the flaws and yellow tinge were removed.

"The process of diamond cutting is effected by a horizontal iron plate of about ten inches diameter, called a *schief*, or *mill*, which revolves from two thousand to three thousand times per minute. The diamond is fixed in a ball of pewter at the end of an arm, resting upon the table in which the plate revolves; the other end, at which the ball containing the diamond is fixed, is pressed upon the wheel by movable weights at the discretion of the workmen. The weight applied varies from 2 to 30 lbs., according to the size of the facets intended to be cut. The recutting of the Koh-i-inoor was commenced on July 16, 1852. His Grace, the late Duke of Wellington being the first person to place it on the mill. The portion first worked upon was that at which the planes F and F meet, as it was neces-
sary to reduce the stone at that part, and so to level the set of the stone before the table could be formed; the intention being to turn the stone rather on one side, and take the incision or flaw at $\pi$, and a fracture on the other side of the stone, not shown in the engraving, as the boundaries or sides of the girdle. The next important step was the attempt to remove an incision or flaw at $c$, described by Professor Tennant and the Rev. W. Mitchell as having been made for the purpose of holding the stone more firmly in its setting, but pronounced by the cutters (after having cut into and examined it) to be a natural flaw of a yellow tinge, a defect often met with in small stones. The next step was cutting a facet on the top of the stone immediately above the last-mentioned flaw. Here the difference in the hardness of the stone first manifested itself; for while cutting this facet, the lapidary noticing that the work did not proceed so fast as hitherto, allowed the diamond to remain on the mill rather longer than usual, without taking it off to cool; the consequence was, that the diamond became so hot from the continual friction and greater weight applied, that it melted the pewter in which it was imbedded. Again, while cutting the same facet, the mill became so hot from the extreme hardness of the stone, that particles of iron mixed with diamond powder and oil ignited. The probable cause of the diamond proving so hard at this part is, that the lapidary was obliged to cut directly upon the angle at which two cleavage planes meet, cutting across the grain of the stone. Another step that was thus considered to be important by the cutters, was removing a flaw at $a$. This flaw was not thought by Professor Tennant and Mr. Mitchell to be dangerous, because if it were allowed to run according to the cleavage, it would only take off a small piece, which it was necessary to remove in order to acquire the present shape. The cutters, however, had an idea that it might not take the desired direction, and, therefore, began to cut into it from both sides, and afterwards directly upon it, and thus they succeeded in getting rid of it. While cutting, the stone appeared to become harder and harder the further it was cut into, especially just above the flaw at $A$, which part became so hard, that, after working the mill at the medium rate of 2,400 times per minute, for six hours, little impression had been made; the speed was therefore increased to more than 3,000, at which rate the work gradually proceeded. When the back (or former top) of the stone was cut, it proved to be much softer, so that a facet was made in three hours, which would have occupied more than a day, if the hardness had been equal to that on the other side; nevertheless, the stone afterwards became gradually harder, especially underneath the flaw at $A$, which part was nearly as hard as that directly above it. The flaw at $A$ did not interfere at all with the cutting. An attempt was made to cut out the flaw at $A$, but it was found not desirable on account of its length. The diamond was finished on September 7th, having taken thirty-eight days to cut, working twelve hours per day without cessation." The weight of the Koh-i-noor since cutting is 1623 carats.

**DIPING.**

1. The Glazier's Diamond is the natural diamond, so set that one of its edges is brought to bear on the glass.

The extreme point of any diamond will scratch glass, making a white streak; but when the rounded edge of a diamond is slid over a sheet of glass with but slight pressure, it produces a cut, which is scarcely visible, but which readily extends through the mass.

Dr. Wollaston succeeded in giving to the ruby, topaz, and rock crystal, forms similar to those of the diamond, and with those he succeeded in cutting glass; proving that this useful property of the diamond depended on its form. Although the primitive form of the diamond is that of a regular octahedron, the Duke de Bourdon has published upwards of one hundred forms of crystallization of the diamond. The irregular octahedrons with round facets are those proper for glaziers' diamonds.

Notwithstanding the hardness of the diamond, yet, in large glass works, as many as one and two dozens are worn out every week: from being convex, they become rapidly concave, and the cutting power is lost.

**DIERS.**

Hardening of. See *Steel, hardening of*, vol. ii.

**DIPPING.**

Ornamental works in brass are usually brightened by a process called *dipping*. After the work has been properly fitted together and the grease removed, either by the action of heat, or by boiling in a pear ash lye, it is pickled in a bath of dilute aqua fortis. It is then scoured bright with sand and water, and being well washed is plunged into the dipping bath, which consists of pure nitrous acid, commonly known as *dipping aqua fortis*, for an instant only, and is then well washed with cold and hot water to remove
DISINFECTANT. Every trace of acid from the surface, after which the work is put into dry beech or box wood, sawdust, &c., well rubbed until it is quite dry, and then barnished and lacquered with as little delay as possible.

DISINFECTANT. A substance which removes the putrid or infected condition of bodies. It is well not to confound it with antisepic, which applies to those bodies which prevent putrefaction. The word disinfectant has lately become somewhat uncertain in its meaning, on account of a word being used as its equivalent, viz., deodorizer. This latter means a substance which removes odors. In reality, however, there are no such substances known to us as a class. There are, of course, some substances which destroy certain others having an odor, but in all cases the removal of the smell and the destruction or neutralization of the body must be simultaneous. There is, however, a large class of substances that destroy putrefaction, and the name disinfectant is therefore distinctly needed. The gases which rise from putrefying bodies are not all capable of being perceived by the senses in their ordinary condition; but sometimes they are perceived. A disinfectant puts a stop to them and deodorizes simultaneously. If any substance were to remove the smell of these gases, it would remove the gases too, as they are inseparable from their property of affecting the nose. A deodorizer would therefore be, and is, a disinfectant of that gas the smell of which it removes. But it has been suggested that it may remove those gases which smell, and allow the most deleterious to pass, they having no smell. Whenever we find such a class of substances, it will be well to give them the name of deodorizers. There may be some truth in the hypothesis that metallic salts remove the sulphur, and by preventing the escape of sulphuretted hydrogen cause less odor, without complete disinfection. But it appears that the decomposition is a prevention of putrefaction in proportion to the removal of that gas in cases where it is given out, and it is quite certain that metallic solutions have disinfecting properties. Any solution having the effect here supposed would at least be a partial disinfectant, inasmuch as the decomposition would be so far put a stop to, as to prevent at least one obnoxious gas. How the others could remain unacted on in this case it is difficult to comprehend. To prevent the formation of one gas is to arrest decomposition or to alter the whole character of the change which is producing the gases. The most deleterious of emanations have no smell at all to the ordinary senses, and we can only judge of the evil by its results, or the fact that the substances capable of producing it are near, or by the analysis of the air. (See Sanitary Arrangements.) The cases where sulphuretted hydrogen accompanies the offensive matter, are chiefly connected with fecal decomposition. This gas is a useful indication of the presence of other substances. So far as is known, the destruction of the one causes the destruction of the other. But the presence of sulphuretted hydrogen is no proof of the presence of infectious matter, nor is its absence a proof of the absence of infectious matter, it being only an occasional accompaniment. When the infectious matter and the odoriferous matter are one, as in the case, as far as we know, of putrid flesh, &c., then to deodorize is to disinfect. We can find then no line of duty to be performed by deodorizers, and no class of bodies that can bear the name, although there may be a few cases where the word may be found convenient. If, for example, we destroy one smell by superadding a greater, that might in one sense be a deodorizing. If we added an acid metallic salt, and removed the sulphuretted hydrogen, letting loose those organic vapors which for a while accompany this act, we might, to those who were not very near, completely destroy smell, and still send a substance into the air by no means wholesome; but in such a case decomposition is stopped, at least for a while. The smelling stage is by no means the most dangerous, nor has the use of the word deodorize any relation to sanitary matters, except in the grossest sense; it is desirable that persons should look far beyond the mere indications furnished by the nose, and as in science we can find no deodorizers, so in practice we need not look for any in the sense usually given to the word. The word may be used for such substances as remove the odor and the putrefaction of the moment, but allow them to begin again. Even in this case deodorizers become temporary disinfectants, which character all removers of smell must more or less have.

Antisepsis, or Colyptic Agents. Substances which prevent decomposition. The words colyptic and colytic come from κόλυξ, to arrest, redress, cut short. This word was proposed by the writer to apply to cases such as are included under antisepsics, antiferments, and similar words. There was needed a word for the general idea. A colyptic force manifests itself towards living persons in anesthetics, anodynes, and uretics, as well, probably, as in other ways. Colytics may probably act from different causes, but these causes not being separately distinguished, a name for the whole class can alone be given. The action of colyptic is entirely opposed to catalysis, which is a loosening up of a compound. Colyptic arrests catalysis, as well as other processes of decomposition, ordinary oxidation for example. Disinfectants, in their character of restraining further decomposition, are included under colytics. One of the most remarkable substances for arresting decomposition is kerosene. It has been used in some condition or mixture from the earliest times. The ancient oil of cedar has been called with good reason turpentine, which has strong disi-
DISINFECTANT.

feet.

fecting properties; but the word has evidently been used in many senses, as there are many liquids to be obtained from cedar. It is used for the first liquid from the distillation of wood; and Berzelius for that reason says that the Egyptians used the pyrophilous acid, which, containing some kreasote, was a great antiseptic. But a mixture of this acid with soda would be of little value in embalming, nor is it probable that they would add a volatile liquid like turpentine along with caustic soda. It is expressly said (in Pliny) that the pitch was reboiled, or, in other words, the tar was boiled and distilled, the product being collected in the wool of fowls, from which again it was removed by pressure. In doing this the light oils or naphtha would be evaporated, and the heavy oil of tar, containing the carabolic acid, or kreasote, would remain. It was called picenum, as if made of pitch or pineum, and picenum or pitch oil, a more appropriate name than that of Rumege's carabolic acid or coal-oil, and still more appropriate than the most recent, which, by following up a theory, has converted it into phenic acid. The distillation was made in copper vessels, and must have been carried very far, as they obtained "a reddish pitch, very clammy, and much fatter than other pitch." This was the anthracene, chrysene, and pyrene of modern chemistry. The remaining hard pitch was called palimpisine, or second pitch, which we call pitch in contradistinction to tar. By the second pitch, however, was sometimes meant the product of distillation instead of what was left in the still. Some confusion therefore exists in the names, but not more than with us. The pitch oil was resinous fat, and of yellow color, according to some. This oil, containing kreasote, was used for toothache—a colytic action applied to living bodies—and for skin diseases of cattle, for which it is found valuable. They also used it for preserving hams.—("Disinfectants," by the Writer. Jour. Soc. of Arts, 1857.)

It is quite possible that kreasote may be the chief agent in most empyreumatic substances which act as antiseptics. But it is not the only agent. Hydrocarbons of various kinds act as antiseptics, as well as alcohol and methyl alcohol, which contain little oxygen. To this class belong essential oils and substances termed perfumes which are used for fumigation, and have also a powerful colytic action. It is exceedingly probable that the true theory of this action is connected with the want of oxygen. These substances do not rapidly oxidize, but, on the contrary, only very slowly, and that chiefly by the aid of other bodies. Their atoms are, therefore, in a state of tension, ready to unite when assisted. As an example, carabolic acid and kreasote unite with oxygen when a base is present, and form rosic acid. We can scarcely suppose that an explanation, commonly resorted to in the case of sulphurous acid, would suit them; viz., that it takes up the oxygen, and so keeps it from the putrescible substance. It is, therefore, much more likely that its condition acts on the putrescible body. For, as the state of motion of a putrefying substance is transferred to another, so is the state of immobility.

An antiseptic preserves from putrefaction, but does not necessarily remove the odor caused by that which has previously putrefied. Many of the substances described as disinfectants here, might equally be called antiseptics. When they remove the putrid matter, they are disinfectants; when they prevent decomposition, they are antiseptics. But when the smell is removed by a substance which is known to destroy putrefactive decomposition, and to preserve organic matter entire, then we have the most thorough disinfection; then we know that the removal of the smell is merely an indication of the removal of the evil.

Disinfectants are of various kinds. Nature seems to use soil as one of the most active. All the dejecta of the animals on the surface of the earth fall on the soil, and are rapidly made perfectly innocuous. Absorption distinguishes porous bodies, and the soil has peculiar facilities for the purpose. But if saturated, it could disintegrate no longer. This is not allowed to occur; the soil absorbs air also, and oxidizes the organic matter which it has received into its pores, and the offensive matter is by this means either converted into food for plants, or has become an innocent ingredient of the air, or, if the weather be moist, of the water. The air is therefore, in conjunction with the soil, one of the greatest disinfectants, but it acts also quite alone and independent of the soil. Its power of oxidizing must be very great. The amount of organic effluvium sent into large towns is remarkable, and yet it seldom accumulates so as to be strongly perceptible to the senses. The air oxidizes it almost as rapidly as it rises; this is hastened apparently by the peculiar agent in the air, ozone, which has a greater capacity of oxidation than the common air; when this is exhausted it is highly probable that the oxidation will be much slower, and this exhaustion does take place in a very short time. So rapid is the oxidation, that the wind, even blowing at the rate of about fifteen to twenty miles an hour, is entirely deprived of its ozone by passing over less than a mile of Manchester. In London this does not take place so rapidly, at least near the Thames. But when the ozone is removed, it is probable that the rate of increase of the organic matter will be much greater. We may by this means, then, readily gauge the condition of a town up to a certain point by the removal of the ozone; but it requires another ability to go further with the other agent that etherizes and dries. This is connected with each other, that the air and the soil best disinfect. When manure is thrown upon land without mixing with the soil, it may require a very long period to obtain thorough disinfection, but when the atmos-

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Where is moist, or rain falls, then the air is rapidly transferred into every portion of the porous earth, and the organic matter becomes rapidly oxidized. To prevent a smell of nature, and with it also the loss of ammonia, it is then needful that as soon as possible the manure should be mixed with the soil. The same power of oxidation is common to all porous bodies, to charcoal, and especially, as Dr. Stenhouse has shown, to planitized charcoal. The use of porous bodies is not so much for the use of preservation, but of slow destruction. It is an oxidation in which all the escaping gases are so thoroughly oxidized, that none of them have any smell or any offensive property. But being so, the body disinfected must necessarily decay, and in reality the process of decay is remarkably increased. All such bodies must therefore be avoided when manures are to be disinfected, as the valuable ingredients are destroyed instead of being preserved. Stenhouse has employed charcoal for disinfesting the air. The air is passed through the charcoal either on a large scale for a hospital, or on a small scale as a respirator for the mouth. Care must be taken, however, to keep the charcoal dry: wet charcoal is not capable of absorbing air until that air is dissolved in the water. This solution takes place less rapidly in water. Wet charcoal is therefore a filter for fluids cificly, and dry charcoal for vapors. Its destructive action on manures will, however, always prevent charcoal from being much used as a disinfectant for such purposes, or, indeed, any other substance which acts principally by its porosity or by oxidation. Thus the soil does only partially, as it has another power, viz., that of retaining organic substances fit to be the food of plants. Although air acts partly in conjunction with the soil and the rain to cause disinfection, and partly by its own power, it also acts mechanically as a means of removing all noxious vapors. The wind and other currents of the air are continually ventilating the ground, and when these movements are not sufficiently rapid, or when they are interrupted by our mode of building, we are compelled to cause them artificially, and thus we arrive at the great advantage in the art of ventilation. The addition of one-tenth of a per cent. of carbonic acid to the air may be perceived, at least if accompanied with the amount of organic matter usually given out at the same time in the breath; and as we exhale in a day 20 cubic feet of carbonic acid, we can injure the quality of 20,000 cubic feet of air in that time. The great value of a constant change of air is therefore readily proved, and the instinctive love which we have of fresh air is a sufficient corroboration.

Cold is a great natural disinfectant. The flesh of animals may be preserved, as far as we know, for thousands of years in ice; putrefying emanations are completely arrested by freezing, but the mobility of the particles, or chemical action, is also retarded by a degree of cold much less than freezing.

Heat is also a disinfectant, when it rises to about 140° of Fahrenheit, according to Dr. Henry. But as a means of producing dryness it is a disinfectant at various temperatures. Nothing which is perfectly dry can undergo putrefaction. On the other hand, heat, with heat with moisture below 140° is a condition very highly productive of decomposition and all its resulting evils. Disinfection by heat is used at quarantine stations. Light is undoubtedly a great disinfectant; so far as we know, it acts by hastening chemical decomposition. In all cases of ventilation, it is essential to allow the rays of light to enter with the currents of air. Its effect on the vitality of the human body is abundantly proved, and is continually asserting itself in vegetation. The true disinfecting power of light exists in all probability in the chemical rays which cause decompositions and decompositions. Water, however, is of all natural disinfectants the most manageable, and there is no one capable of taking its place actively. Wherever animals, even human beings, live, there are emanations of organic matter, even from the purest. The whole surface of the house, furniture, floor, and walls, becomes coated by degrees with a thin covering, and this gradually decomposes, and gives off unpleasant vapors. Sometimes it becomes planted with fungi, and so feeds plants of this kind. But long before this occurs a small amount of vapor is given off sufficiently disagreeable to affect the senses, and sometimes affecting the spirits and the health before the senses distinctly perceive it. This must be removed. In most cases this film is removed by water, and we have the ordinary result of household cleanliness; but in other cases, when the furniture is such as will be injured by water, the removal is made by friction, or by oil or turpentine, and other substances used to polish. Water as a disinfectant is used also in washing of clothes; for this purpose nothing whatever can supply its place, although it requires the assistance both of soap and friction, or agitation and heat. Water is also used as a mechanical agent for removing filth, and the method which Hercules devised of using a river to wash away filth, is now adopted in all the most advanced plans of cleansing towns. It is only by means of water that the refuse of towns can be conveyed away in covered and impervious passages, whilst none whatever is allowed to remain in the town itself. In cases where this cannot be done, it is much to be desired that some disinfecting agent should be used to prevent decomposition. Where water is not used, as in water-deserts, there must of course be a great amount of matter stored up in middens, and the town is of course continually exposed to the effluvia. Besides these methods of acting, water disinfects partly by preventing effluvia from arising from bodies, simply because it keeps them in solution. This action is not a perfect one, but one of great value. The
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water gives off the impurity slowly, sometimes so slowly as to be of no injury, or it keeps it so long that complete oxidation takes place. The oxygen for this purpose is supplied by the air, which the water absorbs without ceasing. To act in this way, water must be delivered in abundance; when only existing as a moisture, water may act as a great opponent to disinfection by rising up in vapor loaded with the products of decomposition.

More drying is known to arrest decay, as the mobility of the particles in decomposition is caused by the want of water. We are told in Andersen's Travels in South Africa, that the Damara cut their meat into strips, and dry it in the sun, by which means it is preserved fresh. A similar custom is found in South America. Certain days prevent this, and decomposition sets in rapidly. A little overcrowding of the sky, or a little more moisture in the air, quickly stops the process.

The above may be called natural disinfectants, or imitations of natural processes, charcoal being introduced as an example of a more decided character of porous action. They show both mechanical and chemical action. The mechanical, when water or air removes, dilutes, or covers the septic bodies: the chemical, when porous bodies act as conveyers of oxygen: or an union of both, when cold and heat prevent the mobility of the particles. The action by oxidation causes a destruction of the offensive material. The other method is antiseptic. It is much to be desired that all impurities should be got rid of by some of these methods, but especially by the air, the water, and the soil. There are, however, conditions in which difficulties interfere with the action. Large towns may be purified by water, but what is to be done with the water which contains all the impurity? If put upon land, it is very soon disinfect, but on its way to the land it may do much mischief. It has been proposed to disinfect it on its passage, and even in the sewers themselves; by this means the town itself is freed from the nuisance, and the water may be used where it is needed without fear. This introduces artificial disinfectants. There are other cases where such are required—when the refuse matter of a town is allowed to lie either in exposed or in underground receptacles; in this case a town is exposed to an immense surface of impurity, and disinfectants would greatly diminish the evil, if not entirely remove it. There arc, besides, special cases without end continually occurring, where impurities cannot be at once removed, and where treatment with artificial disinfectants is required.

Artificial disinfectants which destroy the compound, are of various kinds. Fire is one of the most powerful. A putrid body, when heated so as to be deprived of all volatile particles, cannot any longer decompose. It is however possible that the vapors may become putrid, and if not carefully treated, this will happen. It was the custom of some of the wealthy among the ancients to burn the dead, and it is still the custom in India; but although the form is kept up amongst all classes, the expense is too great for the poor. The bodies are shoted, or even lost touched by fire, and thrown if possible into the river. This process has been recommended here, but the quality of the gaseous matter rising from a dead body, is most disgusting to our physical, and still more to our moral senses, and the amount is enormous. It is of course possible to burn it, that only pure carbonic acid, water, and nitrogen, shall escape; but the probability of preventing all escape is small enough to be deemed an impossibility, and the escape of one per cent. would cause a rising of the whole neighborhood. To effect the combustion of the dead of a great city, such a large work, furnished with great and powerful furnaces, would be required, that it would add one of the most frightful blots to modern civilization, instead of the calm and peaceful churchyard, where our bones are preserved as long at least as those who care for us live, and then gradually return to the earth. In burning the dead, some prefer to burn the whole body to pure ash. This was the ancient method; but it is highly probable that the ashes which they obtained were a delusion in most cases. The amount of ash found in the urns is often extremely small. The body cannot be reduced to an infinitesimal ash, as is supposed; eight to twelve pounds of matter remain from an average man when all is over. A second plan, is to drive off all volatile matter, and leave a cinder. This disgusting plan leaves the body black and incorruptible. It can never, in any time known to us, mix with its mother earth, and yet ceases at once to resemble humanity in the slightest degree; it will not even for a long time assist us by adding its composition to the fertility of the soil. The burning of bodies never could have been general, and never can be general. Fire has only a limited use as a disinfectant. It cannot be used in the daily disinfection of the defeca of animals, and is applied only occasionally, where the most rapid destruction is the most desirable, either because the substance has no value, or it is too disgusting to exist, or the products after burning are not offensive. There are two methods of using fire, clarifying or burning to ashes. The second is an act of Oxidation.—This is effected either by rapid combustion called fire; by slow combustion, the natural action of the air; or by chemical agency, sometimes assisted by mechanical. Slow oxidation in the soil is a process which is desirable in every respect, and it would be well if we could bring all offensive matter into this condition; the ammonia is preserved, or it is in part oxidized into nitric acid and water, both the ammonia and nitric acid being food for plants. Sometimes this process is hastened by mixing up the manure with alkaline
substances, raising it in heaps, and watering, by this means forming nitrates, a process performed abundantly in warm countries upon the materials of plants and animals, and imitated even in temperate regions with success. This amount of oxidation destroys a good deal of the carbonaceous substances, and leaves less for the land. It is only valuable when salt-petre is to be prepared.

One of the most thorough methods of oxidation, is by the use of the manganates or permanganates. They transfer their oxygen to organic substances with great rapidity, and completely destroy them. They are therefore complete disinfectants. They destroy the odor of putrid matter rapidly, and oxidize sulphuretted hydrogen, and phosphuretted hydrogen, as well as purely organic substances. As they do this by oxidation at a low temperature, they are the mildest form of the destructive disinfectants, and their application to putrid liquids of every kind will give most satisfactory results. The quantities treated at a time should not be great, and the amount of material used must be only to the point of stopping the smell, or at least not much more, because both pure and impure matter act on the manganates, and an enormous amount of the material may be used in destroying that which is not at all offensive. The manganates do not prevent decay from beginning again. Their use has been patented by Mr. Condy. A similar action takes place with various high oxides and other oxides which are not high. Sometimes, however, a deleterious gas is produced, as a secondary result by oxidation, as when sulphuric acid in the sulphates oxidizes organic matter, allowing sulphuretted hydrogen to escape. In this case it is highly probable that a true disinfection takes place, or a destruction of the putrid substance, and all offensive purely organic substances; still the amount of sulphuretted hydrogen given off, is of itself sufficiently offensive and deleterious, although not, properly speaking, an infectious or putrid gas, but an occasional accompaniment.

Nitric acid is another agent of destruction or oxidation, although it has qualities which might cause it to be ranked amongst those which prevent the decomposition by entering into new combinations. But properly speaking, it is not nitric acid which is the disinfectant of Carmichael Smyth, but nitric oxide, which is a powerful oxidizer, and most rapidly destroys organic matter. For very bad cases, in which gaseous fumigation is applicable, nothing can be more rapid and effective in its action than this gas. Care must be taken that there is no one present to breathe it, as it has a powerful action on the lungs, and care must be taken that metallic surfaces which are to be preserved clean, be well covered with a coating of varnish. This was used with great effect in ships and hospitals for some years, beginning with 1780, and so much good did it do, that the Parliament in 1802 voted Dr. C. Smyth a pension for it. Guyton-Morveau was vexed at this, and wrote an interesting volume concerning his mode of fumigating by acids; but in reality acids alone are insufficient, and his favorite muriatic acid has no such effect as nitrous fumes, which so readily part with their oxygen.

Chlorine is another destructive agent, and its peculiar action may be called an oxidation. When used as a gas, it has a great power of penetration, like nitrous fumes, and stops all putrefaction. It has a more actively destructive power than oxygen alone, even when its action is that of oxidation only. It decomposes compounds of ammonia into water and nitrogen, and as putrefactive matter is united with, or combined partly of nitrogen, it destroys the very germ of the evil. By the same power it destroys the most expensive part of a manure, the ammonia. It cannot therefore be used where the offensive matter is to be retained for manure. When chlorine is united with lime or soda, it may be used either as a powder in the first case, or as a liquid in either case. For direct application to the offensive substances, a solution is used, or the powder. This latter acts exactly as the gaseous chlorine, but the power of destroying ammonia is greater. As a liquid, it acts too rapidly; as a solid, the chloride of lime soon attracts moisture, and soon loses its power. Some people use the chloride of lime as a source of chlorine; they pour sulphuric acid on it, and so cause it to give out chlorine, which escapes as a gas, and acts as aforesaid. This has not been found agreeable, or indeed more than partially useful. Too much is given out at first, too little at last. It is said to have increased the lung diseases at hospitals, where it was much used in Paris. When only a minute quantity of gas is given out, as at bleach works, it certainly causes a peculiar freshness of feeling, and the appearance of the people is much in its favor, nor has it ever there been known to affect the lungs. For violent action, in cases of great impurity, it is a great disinfectant, and to be preferred to nitrous fumes, probably causing a less powerful action on the lungs. Eau de javelle is a chloride of potash used in Paris. Sometimes oxygen, or at least air, is used alone, to remove both color and smell, oils having it pumped in. Sometimes acids alone are used for disinfections. As putrid compounds contain ammonia or organic bases, they may be removed, or at least they may be retained in combination, and in this way restrained from further evaporation. This seems to be the way in which muriatic acid acts, and all other merely acid agents. This acid, so much valued at one time, is now entirely disused, as it ought to be, because it is exceedingly disagreeable to breathe, and destructive of nearly all useful substances which it touches, being at the same time a very indirect disinfectant. Acids
poured on putrid matters, no doubt destroy the true putrefaction, but they cause the evolution of gases exceedingly nauseous, and of course unwholesome. This evolution does not last long, but long enough to make them useless as disinfectants when used so strong. Vinegar is the best of the pure liquid disinfectants; wood vinegar the best of the vinegars, because it unites to the act a very little kreasote. Vinegar is a very old and well-established agent; it has been used in the case of plague and various pestilences from time immemorial. It is used to preserve catables of various kinds. For fumigation, no acid vapor used is pleasant except vinegar, and in cases where the impurity is not of the most violent kind, it may be used with great advantage. Even this, however, acts on some bright surfaces, a disadvantage attending most fumigations.

Sulphurous Acid, or the fumes of burning sulphur, may be treated under this head, although in reality it does not act as a mere acid combining with a base and doing no more. It certainly unites with bases so that it has the advantage of an acid, but it also decomposes by precipitating its sulphur, as when it meets sulphurate hydrogen. It therefore acts as an oxidizer in some cases, but it is generally believed, from its desire to obtain oxygen, that it acts by being oxidized, thus showing the peculiar characteristics of a deoxidizer. We can certainly believe that bodies may be disinfected both by oxidation and deoxidation. The solutions of sulphurous acid act as a restraint on oxidation, and preserve like vinegar. Its compounds with bases, such as its salts of soda, potash, &c., preserve also like vinegar, salt-petre, &c.; probably from their affinity for oxygen, taking what comes into the liquid before the organic matter can obtain it. But it is not probable that this rivalry exists to a great extent; the presence of the sulphurous acid in all probability puts some of the particles of oxygen in the organic matter in a state of tension or inclination to combine with it, so that the tension of the particles which are inclined to combine with the oxygen of the air is removed.

Sulphur fumes are amongst the most ancient disinfectants held sacred in early times from their wonderful efficacy, and still surpassed by none. With sulphur, the shepherd purified or disinfected his flocks, and with sulphur Ulysses disinfected the suitors which he had slain in his house. No acid fumigation is less injurious generally, vinegar excepted, to the lungs or furniture, and its great efficiency marks it out as the most desirable, although much laid aside in modern times. The amount arising from burning coal must have a great effect in disinfesting the putrid air of our streets, and rendering coal-burning towns in some respects less unpleasant; this is one of the advantages which that substance brings along with it, besides, it must be confessed, greater evils. It is curious that this compound of sulphur should be one of the most efficient agents in destroying sulphurate hydrogen, another compound of sulphur. Sulphurous acid prevents decomposition, and also preserves the valuable principle of manure, so that it belongs partly to the class of disinfectants, and partly to antiseptics.

The peculiar actions of sulphurous acid and kreasote have been united in that called "McHoughall's Disinfecting Powder." Since in towns and farms, when disinfectants are used, it is desirable not to use liquids, these two have been united into a powder, which assists also in removing moisture, as water is often a great cause of discomfort and disease in stables and cowhouses. When they are used in this manner, the acids are united with lime and magnesia. When the floors of stables are sanded with the powder, it becomes mixed with the manure, which does not lose ammonia, and is found afterwards much more valuable for land. The cattle are also freed from a great amount of illness, because the air of the stable is purified. When fumes of any kind cannot be at once removed by water, as by the water-closet system, the use of this is invaluable; but it is well to know that the instant removal of impurity by water is generally best for houses, however difficult the after problem may be when the river is polluted. In stables and cowhouses this is not the case, and it is then that a disinfecting powder becomes so valuable, although it is true that so many towns are unfortunately so badly supplied with water-closets that disinfectants are still much wanted for the middens.

The inventors have proposed to disinfect sewers, as well as sewage, by the same substances; not, however, in the state of a powder. They apply the acids to the sewage water in the sewers themselves, and so cause the impure water to pass disinfected through the town; by this means the towns and sewers are purified together. When the sewage water is taken out of the town it can be dealt with either by precipitation or otherwise. As it will cease to be a nuisance, covered passages for it will not require to be made.

Lime is used for precipitating sewage water, and acts as a disinfectant as far as the removal of the precipitate extends, and also by absorbing sulphurated hydrogen, which, however, it allows again to pass off gradually. The other substances proposed for sewers have chiefly relation to the precipitation, and do not so readily come under this article. Charcoal has been mentioned; alum has been proposed, and it certainly does act as a disinfectant and precipitant. None of these substances have been tried on a great scale excepting lime.
DISTILLATION.

Absence of Air is an antiseptic of great value. The process of preserving meat, called Appert's process, is by putting it in tin vessels with water, boiling off a good deal of steam, to dress out the air, and then closing the aperture with solder. Schroeder and De Duchs prevented putrefaction for months by allowing no air to approach the meat without passing through cotton; so also veils are found to be a protection against some miasmas. Salt, or compounds of acids with bases, are valuable antiseptics; some of them are also disinfectants, that is, they remove the state of putrefaction after it has begun. An antiseptic prevents it, but does not necessarily remove it. Common salt is well known as a preserver of flesh; nitrate of potash, or saltpetre, is a still more powerful one. Some of these salts act in a manner not noticed when treating of the preceding substances, viz., by removing the water. Meat, treated with these salts, gives out its moisture, and a strong solution of brine is formed. Chloride of calcium prevents, to some extent, the putrefaction of wood. Alum, or the sulphate of alumina, is not a very efficient preserver; but chloride of aluminium seems to have been found more valuable. It is sometimes injected into animals by the carotid artery and jugular vein. Meat usually keeps a fortnight: if well packed, cleaned, and washed with a solution of chloride of aluminium, it will keep three months. But in reality the salts of the heavier metals are of more activity as disinfectants. It has been supposed that their efficiency arose from their inclination to unite with sulphur and phosphorus, and there is no doubt that this is one of their valuable properties, by which they are capable of removing a large portion of the impure smell of bodies; but they have also an inclination to combine with organic substances, and by this means they prevent them from undergoing the changes to which they are most prone. The actual relative value of solutions it is not easy to tell. Most experiments have been made on solutions not sufficiently definite in quantity. Salts of mercury have been found highly antiseptic. Such a salt is used for preserving wood; the process is known as that of Kyan's, or kyanizing. A solution of corrosive sublimate, containing about 14 per cent. of the salt, is pressed into the wood either by a forcing pump or by means of a vacuum. The alumbein is the substance most apt to go into putrefaction, and when in that condition it conveys the action to the wood. It is no doubt that its action on the alumbein that the mercury chiefly acts. Thin pieces of pine wood, saturated for four weeks in a solution of 1 to 25 water, with the following salts, were found, after two years, to be preserved in this order:—1. Wood alone, brown and crumbling. 2. Alum, like No. 1. 3. Sulphate of manganese, like 1. 4. Chloride of zinc, like 1. 5. Nitrate of lead, somewhat firmer. 6. Sulphate of copper, less brown, firm. 7. Corrosive sublimate, reddish yellow and still firmer. In an experiment, in which linen was buried with similar salts, the linen was quite consumed, even the specimen with corrosive sublimate. Other experiments showed salts of copper and mercury to protect best.—Gmelin.

Nevertheless, all these metallic salts are found true preservers under other conditions. Chloride of manganese, a substance frequently thrown away, may be used, as Gay-Lussac and Mr. Young have shown, with great advantage, and Mr. Boucher's has shown the value of the acetate of iron. Mr. Boucher's process is very peculiar. He feeds the tree, when living, with the acetate of iron, from pouring it into a trough dug around the root. The tree, when cut down, has its pores filled with the salt, and the alumbein in the sap is prevented from decomposing. For preservation of vegetable and animal substances, see Putrefaction, Prevention of.

The chloride of zinc of Sir William Burnett is also a valuable disinfectant, and has more power than it would seem to possess from the experiments quoted about. Wood, cords, and canvas, have been preserved by it under water for many years. It has the advantage also of being so soluble as to take up less room than most other salts, although liquids generally are inconvenient as disinfectants in many places.

Nitrate of lead is a disinfectant of a similar kind; it lays hold of sulphur, and the base unites with organic compounds. All these metals are too expensive for general use, and can only be applied to the preservation of valuable materials. Even iron is much too dear to be used as a disinfectant for materials to be thrown on the fields as manure. All are apt to be very acid, a state to be avoided in a disinfectant, unless when it is applied to substances in a very dilute state, or in an active putrid state, and giving out ammonia.—R. A. S.

See also Sanitary Economy.

DISTILLATION. Distillation consists in the conversion of any substance into vapor, in a vessel so arranged that the vapors are condensed again and collected in a vessel apart.

The word is derived from the Latin dis and stilto, I drop, meaning originally to drop or fall in drops, and is very applicable to the process, since the condensation generally takes place dropwise.

It is distinguished from sublimation by the confinement of the latter term to cases of distillation in which the product is solid, or, in fact, where a solid is vaporized, and condensed without visible liquefaction.

The operation may simply consist in raising the temperature of a mixture sufficiently to
evaporate the volatile ingredients; or it may involve the decomposition of the substance heated, and the condensation of the products of decomposition, when it is termed destructive distillation; in most cases of destructive distillation the bodies operated upon are solid, and the products liquid or gaseous; it is then called dry distillation.

In consequence of the diversity of temperatures at which various bodies pass into vapor, and also according to the scale on which the operation has to be carried out, an almost endless variety of apparatus may be employed.

Whatever be the variety of form, it consists essentially of three parts:—the retort or still, the condenser, and the receiver.

On the small scale, in the chemical laboratory, distillation is performed in the simplest way, by means of the common glass retort $a$, and receiver $b$, as in fig. 221. The great advantages of the glass retort are that it admits of constant observation of the materials within, that it is acted upon or injured by but few substances, and may be cleaned generally with facility. Its great disadvantage is its brittleness.

The retort may be either simple, as in fig. 223, or tubulated, as in fig. 221, (a.)

Retorts should generally be chosen sufficiently convex in all parts, the degree of curvature of one part passing gradually into that of the neighboring portions, as is represented in the figure; the part to be heated should, moreover, be as uniform in point of thickness as possible. The tubulated retort is more liable to crack than the plain one, on account of the necessarily greater thickness of the glass in the neighborhood of the tubulature; nevertheless it is very convenient on account of the facility which it offers for the introduction of the materials.

In charging retorts, if plain, a funnel with a long stem should be employed, to avoid soiling the neck with the liquid to be distilled: when a solid has to be introduced, it is preferable to employ a tubulated retort; and if a powdered solid is to be mixed with a fluid, it is preferable to introduce the fluid first.

Heat may be applied to the retort either by the argand gas flame, as in fig. 221, or a water, oil, or sand-bath may be employed.

In distilling various substances, e. g., sulphuric acid, great inconvenience is experienced, and even danger incurred, by the phenomenon termed "bumping." This consists in the accumulation of large bubbles of vapor at the bottom of the liquid, which bursting cause a forcible expulsion of the liquid from the retort. It is prevented by the introduction of a few angular fragments of solid matter of such a nature as not to be acted upon by the liquid which is to be distilled. Nothing answers this purpose better than a piece of platinum foil cut into a fringe, or even a coil of platinum wire introduced into the cold liquid before the distillation is commenced. Even with this precaution the distillation of sulphuric acid, which it is often desirable to perform for the purpose of its purification, is not unattended with difficulty and danger.

Dr. Mohr suggests the following method*:—A glass retort of about two pounds' capacity, is placed on a cylinder of sheet-iron in the centre of a small iron furnace, while its neck protrudes through an opening in the side of the furnace. (fig. 223.) Ignited charcoal is placed round the cylinder, without being allowed to come in contact with the glass, and a current of hot air is thus made to play on all parts of the retort excepting the bottom, which

* Mohr and Redwood's Practical Pharmacy.
is protected by its support. There is a valve in the flue of the furnace for regulating the draught, and three small doors in the cupola or head, for supplying fresh fuel on every side, and for observing the progress of the distillation.

Instead of the sheet-iron cylinder, a Hessian crucible may be employed, and this, if requisite, elevated by placing it on a brick. If the vapor be readily condensed, nothing more is necessary than to insert the extremity of the retort into a glass receiver, as in fig. 221.

If a more efficient condensing arrangement be requisite, nothing is more convenient for use on the small scale than a Liebig's condenser, shown in fig. 224. It consists simply of a long glass tube into which the neck of the retort is fitted, and the opposite extremity of which passes into the mouth of the receiver; round this tube is fitted another either of glass or metal, and between the two a current of water is made to flow, entering at a and passing out at b. The temperature of this water may be lowered to any required degree by putting ice into the reservoir e, or by dissolving salts in it. (See Freezing.)

Even on the small scale it is sometimes necessary to employ distillatory apparatus constructed of other materials besides glass.

Earthenware retorts are now constructed of very convenient sizes and shapes. There is one kind—which is very useful when it is required to pass a gas into the retort at the same time that the distillation is going on, as in the preparation of chloride of aluminium, &c.—which has a tube passing down into it also made of earthenware, as in fig. 225. The closest are of Wedgewood ware, but a common clay retort may be made impermeable to gases, by washing the surface with a solution of borax, then carefully drying and heating them.

Retorts, or flasks with bent tubes, which screw in thus, (fig. 226,) of copper, are employed when it is requisite to produce high temperatures, as for the preparation of benzole from benzoic acid and baryta, or in making marsh gas from an acetate, &c.

In distilling hydrofluoric acid, the whole apparatus should be constructed in lead; the receiver consisting of a U-shaped tube of lead, which is fitted with leaden stoppers so as to serve for keeping the acid when prepared; or a receiver of gutta percha may be employed with a stopper of the same material. (Fig. 227.)

For many purposes in the laboratory, as, for instance, the preparation of oxygen by
heating binoxide of manganese,—in the manufacture of potassium, &c., &c., where high temperatures are required, the iron bottles in which mercury is imported from Spain may be employed, a common gun-barrel being screwed into them to act as a delivery tube or condenser. (Fig. 228.)

On a large scale an almost endless variety of stills have been and are still employed, which are constructed of different materials.

The common "still" consists of a retort or still proper, in which the substance is heated; and a condenser commonly called a "worm," on account of its having frequently a spiral shape. The retort or still is generally made in two parts; the pan or copper, which is the part to which heat is applied, and is commonly set in a furnace of brickwork, and the "head," which is generally removed after each operation, and refixed and luted upon the pan when again used. The condenser or worm is commonly placed in a tube or other vessel of water. (See fig. 231.)

The still may be either constructed of earthenware, or, as is very commonly the case, of copper, either plain or electro-plated with silver, according to circumstances; less frequently platinum is employed.

The still is either heated by an open fire, as in fig. 228, or, as is now very commonly the case, by steam. The still-pan (fig. 229) is surrounded by an outer copper jacket, and steam is admitted between them from a steam-boiler under any required pressure. In this way the temperature may be regulated with the greatest nicety.

Various adaptations for heating by steam have been appropriately arranged in a very convenient form by Mr. Coffey, of Bunhill Row, Finsbury, in his so-called Esculapian Still. It is in fact a veritable multum in parvo, being intended to afford to the pharmaceutical chemist the means of conducting the processes of ebullition, distillation, evaporation, de-
siccation, &c., on the small scale, by the heat of a gas-furnace. The following cut (fig. 230) represents this apparatus.

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b, a burner supplied with gas by a flexible tube. c, the boiler or still. 1, an evaporating pan fixed over the boiler and forming the top of the still-head. k, a valve for shutting off the steam from 1, when it passes through the tube m; otherwise it would pass through l, and communicate heat to the drying-closet o o, and from thence to the condenser t t. o is a second evaporating pan over the drying-closet. Another arrangement for distilling by steam is shown in fig. 231.

Sometimes also distillation is effected by passing hot steam through a worm contained within the still, instead of or in addition to, the application of heat from without.
The worm or condenser is frequently constructed of earthenware, and set in an earthenware vessel; these are very convenient when the operation is not to be conducted on a very large scale, and only at a moderate temperature. They are now to be obtained of all manufacturers of stome-ware articles. More commonly the worm is of copper, tin, or copper lined with silver, and in some rare cases, where the liquids to be distilled act upon both copper and silver, of platinum. (Fig. 232.)

A tube of the shape shown in fig. 233 is found more convenient than the worm, on account of its exposing a larger surface, and also because it can be placed into a vessel of a prismatic form which occupies but little space. The water employed for condensation enters at the bottom and passes out at the top.

![Diagram of a worm condenser](image)

*Gaddis's Condenser* is represented in fig. 234. It consists of two conical vessels of metal, of unequal size, the smaller being fixed within the other, and the space between them closed at the bottom. These are placed in a tub filled with cold water, which comes in contact with the inner and outer surfaces of the cones, while the space between is occupied by the vapor to be condensed. This condenser is subject to the objection which applies to the common worm, that it cannot be easily and efficiently cleaned.

To obviate this, Professor Mitscherlich has proposed a very simple modification in its form, in which the inner cone is movable, so that, when taken out, the intervening space between it and the outer cone can be cleaned, and then the inner cone replaced previously to commencing an operation.

*Distillation of Spirits.*—In the manufacture of *ardent spirits*, the alcoholic liquor obtained by fermentation of a saccharine solution is submitted to distillation; the alcohol, being more volatile than the water, passes over first, but invariably a considerable proportion of water is evaporated and condensed with the alcohol. To separate this water to the required extent, it is necessary either to submit the product to redistillation, or to contrive an apparatus such that the product of this first distillation is returned to the still until a spirit of the required strength is obtained.

One of the earliest and simplest contrivances for effecting the latter object is the still invented by Dorn, which is employed up to the present time in Germany. (Fig. 235.) \(a\) is the still, heated by the direct action of the fire; \(b\) the head, from which \(v\) conveys vapor to a small refrigerator, for the purpose of testing the strength of the distillate; \(z\) is an ordinary condenser containing worm, &c. The intermediate copper vessel answers two purposes; the upper part \(c\) forming a heater for the wash, while the lower compartment \(n\) acts as a rectifier. The heater \(c\), when filled up to the level of the cock \(m\), contains the exact measure of wash for charging the still; the contents can be constantly agitated by the rouser \(i\). The still and heater being both charged, the vapor will at first be completely condensed in passing through the worm \(g\), and flowing into \(v\) will close the aperture. When the contents of \(c\) become so hot that no more condensation occurs, the vapor will escape by bubbling through the liquid in \(v\), which latter rapidly becomes heated to the boiling point, and evolves vapors richer in alcohol, which in their turn are condensed in \(z\).

In this manner, by one operation, spirit containing about 60 per cent. of alcohol is obtained.

Of the recent improvements on Dorn's still, two only need be described:—Coffey's, which has in a great measure replaced all others in this country, and Derosne's, which is extensively employed in France.
Coffey's Still far surpasses any of those before described. It was patented in 1832, and has proved most valuable to the distiller, since it yields the strongest spirit that can be obtained on the large scale.

Its objects are twofold:—1st, to economize the heat as much as possible, by exposing the liquid to a very extended heated surface; 2d, to cause the evaporation of the alcohol from the wash by passing a current of steam through it.

The wash is pumped from the "wash charger" into the worm tube, which passes from top to bottom of the rectifier. In circulating through this tube its temperature is raised to a certain extent. Arrived at the last convolution of the tube in the rectifier, the wash passes by the tube \( a \) in at the top of the "analyzer." It falls and collects upon the top shelf until this overflows, whence it falls on to the second shelf, and so on to the bottom. All the while steam is passed up from the steam-boiler through fine holes in the shelves, and through valves opening upwards. As the wash gradually descends in the analyzer, it becomes rapidly weaker, partly from condensation of the steam which is passed into it, and partly from loss of alcohol, either evaporated or expelled by the steam; till, when it arrives at the bottom, it has parted with the last traces of spirit. At the same time the vapor, as it rises through each shelf of the analyzer, becomes continuously richer in alcohol, and contains less and less water in consequence of its condensation; it then passes from the top of the analyzer in at the bottom of the lower compartment of the rectifier. Here it ascends in a similar way, bubbling through the descending wash, until it arrives at \( r \), above which it merely circulates round the earlier windings of the wash-pipe, the low temperature of which condenses the spirit, which, collecting on the shelf at \( r \), flows off by the tube into the finished spirit condenser.

In order still further to economize heat, the water for supplying the boiler is made to pass through a long coil of pipe, immersed in boiling-hot spent wash, by which means its temperature is raised before it enters the boiler. In fact, the saving of fuel by the employment of this still is so great, that only about three-fourths of the quantity is consumed that would be requisite for distilling any given quantity of alcohol in the ordinary still; and Dr. Muspratt estimates that in this way a saving will be effected throughout the kingdom of no less than 140,000 tons of coal per annum.

Very few persons have any idea of the enormous size of some of the distilleries. One of Mr. Coffey's stills at Inverkeithing works off 2,000 gallons of wash per hour, and one, more recently erected at Leith, upwards of 3,000 gallons.

Derosne's Still is very similar, in the principle of its action, to Coffey's, differing in fact only in the mechanical details by means of which the result is obtained.

It consists of two stills, \( a \) and \( b \), fig. 237. The mixture of steam and alcohol vapor from \( a \) passes into the liquid in \( n \), which it raises to the boiling point. The vapors from \( a \) rise through the distillatory column \( c \) and \( n \), (the rectifying column:) hence they traverse the coils of tubing in \( e \), (the condenser and wine-heater,) and the alcohol is finally condensed by traversing the worm in \( f \), (the refrigerator,) whence it is delivered at \( z \). At the same time a steady current of the original alcoholic liquor is admitted from the reservoir \( h \), into the exterior portion of the condenser \( e \), by means of the tap, the flow of which is regulated by the bell cock \( g \). Whilst condensing the spirit in the worm, the wash has its temperature raised, especially in the upper part, and thence it ascends by the tube \( b \) into the heater \( e \), by the small orifices \( k k \), fig. 238, where it is still further heated by the current of heated alcohol which has risen into the worm from the stills, whilst at the same time

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Improved Apparatus of Arnest Colling & Sons, of Bromley, near Bromley, for the Distillation of Spirit.
assisting in the condensation of the spirit. After performing its office of condensation, and when nearly at the boiling point, the alcoholic liquor passes out by the tube \( l \), and is conducted to the top of the distillatory column \( c \). Here it trickles down over a series of lenticular discs of metal, (shown in fig. 238,) so contrived as to retard its progress into the still \( n \), and yet permit the ascent of the steam. In this distillatory column \( c \), (fig. 240) it meets the steam rising from the still \( n \). The greater part of its alcohol is expelled, which, traversing the series of condensers before described, is ultimately liquefied and collected at \( z \); but, to complete the rectification, it descends into the still \( n \), and, when above a certain level, \( m \), into \( a \), which stills being heated by a furnace beneath, the final expulsion of alcohol is accomplished, and the spent liquor run off at \( x \).
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The details of the construction of the apparatus employed in the distillation of spirits have been here given, since this process is perhaps one of the most important of the kind; but various modifications are employed in the distillation of other liquids.

In some cases, unusually effectual condensing arrangements are required, as in the manufacture of Ether, Chloroform, Bisulphide of Carbon, and Bichloride of Carbon.

In others higher temperatures are necessary, as in the distillation of sulphuric acid.

When the liquids to be distilled are acid, or otherwise corrosive, great care has to be taken especially that the worm or other condenser is of a material not acted upon by the acid. See Acetic Acid and Sulphuric Acid.

The term distillation is sometimes applied to cases of the volatilization and subsequent condensation of the metals either in their preparation or purification.

In cases like mercury, potassium, and sodium, where they are condensated in the liquid state, or visibly pass through this state before volatilization, this term is quite appropriate; but when the fusing and vaporizing points nearly coincide, as in the case of arsenic, the term sublimation would be more suitable.

Nevertheless it is difficult to draw a precise line of demarcation between the two terms; for in the cases of zinc, cadmium, &c., the metals being melted before volatilization, and condensed likewise in the liquid state, the term is certainly correct.

For the details of construction of the distillatory apparatus, we must refer to the articles on these several metals.

Distillatio per descensum is a term improperly applied to certain cases of distillation where the vapor is dense, and may be collected by descending through a tube which has an opening in the top of the distillatory vessels, and descends through the body of the vessel in which the operation of evaporation is going on, being collected below.

This is clearly merely due to the fact of the vapor being even at a high temperature more dense than atmospheric air, and might be performed with any body forming a dense vapor, such as mercury, iodine, zinc, &c.

It has, however, practically been confined to the English process of refining zinc. See Zinc.

The two most remarkable cases in which the process of destructive distillation is carried out on a manufacturing scale, are the dry distillation of wood, for the manufacture of wood charcoal, acetic acid, and pyrolitic spirit, (which see,) and of coal, for the purpose of obtaining coal-gas, and coke. This process will be found fully described in the article on Coal-Gas.

Distillation of Essential Oils or Essences.—The separation of volatile flavoring oils from plants, &c., by distillation with water, will be fully treated under another head. See Perfumery, Essences.

Fractional Distillation.—A process for the separation of volatile organic substances (such as oils) is very extensively employed in our naphtha works under this name.

If we have two volatile bodies together, but differing appreciably in their boiling points, we find, on submitting them to distillation in a retort, through the tubalature of which a thermometer is fixed, so that its bulb dips into the liquid, that the temperature remains constant (or nearly so) at the point at which the more volatile constituent of the mixture boils, and the distillate consists chiefly of this more volatile ingredient; and only after nearly the whole of it has passed over, the temperature rises to the point at which the less volatile body boils. Before this point has been reached, the receiver is changed, and the second distillate collected apart. By submitting the first product to repeated redistillation, as long as its boiling point remains constant, the more volatile constituent of the mixture is ultimately obtained in a state of absolute purity. See Naphtha.

This method may in fact be adopted when the mixture contains several bodies; and by changing the receiver with each distinct rise of temperature, and repeating the process several times, a fractional separation of the constituents of the mixture may be effected.—H. M. W.

DISTILLATION, DESTRUCTIVE. Organic matters may be divided into two groups, founded on their capability of withstanding high temperatures without undergoing molecular changes. Bodies that distil unchanged form the one, and those which break up into new and simpler forms, the other. The manner in which heat acts upon organic substances differs not only with the nature of the matters operated upon, but also with the temperature employed. We shall study the subject under the following heads:

1. Apparatus for Destructive Distillation.
2. Destructive Distillation of Vegetable Matters.
4. Destructive Distillation of Acids.
5. Destructive Distillation of Alcohols.

1. Apparatus for Destructive Distillation.—Destructive distillation on a large scale is
most conveniently performed in the cast-iron retorts used in gas works. Where quantities of materials not exceeding fifteen or twenty pounds are to be operated on, for the purpose of research, a more handy apparatus can be made from one of the stout cast-iron pots sold at the iron wharves. They are semi-cylindrical, and have a broad flange round the edge. The cover should be made to fit in the manner of a saucepan lid. The aperture by which the products of distillation are to be carried away should be of good size, and the exit pipe must not rise too high above the top of the pot before it turns down again. This is very essential in order to prevent the loss volatile portion of the distillate from condensing and falling back. The exit tube should conduct the products to a receiver of considerable capacity, and of such a form as to enable the solid and fluid portions of the distillate to be easily got at for the purpose of examination. From the last vessel another tube should conduct the more volatile products to a good warm supplied with an ample stream of cold water. If it be intended to examine the gaseous substances yielded by the substances under examination, the exit pipe of the worm must be connected with another apparatus, the nature of which must depend on the class of bodies which are expected to come over. If the most volatile portions are expected to be basic, it will be proper to allow them to stream through one or more Woulté's bottles half filled with dilute hydrochloric acid. Any very volatile hydrocarbons of the C6H6 family which escape may be arrested by means of bromine water contained in another Woulté's bottle. The pressure in the Woulté's bottles must be prevented from becoming too great, or the leakage between the flange of the pot and its cover will be very considerable. The huting may consist of finely sifted Stourbridge clay, worked up with a little horse dung. A few heavy weights should be placed on various parts of the lid of the pot, so as to keep it close, and render the leakage as little as possible. For the destructive distillation of small quantities of substances, I have been accustomed for a long time to employ a small still made from a glue-pot, and having a copper head made to fit it. The huting for all temperatures not reaching above 70° may be a mixture of 2 lb. linseed and 1 lb. almond meal, made into a mass of the consistence of putty. For the apparatus employed in the destructive distillation of wood, coal, bones, &c., on the large scale, the various articles in this work on the products obtained from these substances must be consulted.

2. Destructive Distillation of Vegetable Matters.—The principal vegetable matters which are distilled on the large scale are wood and coal. We shall consider these separately.

Destructive Distillation of Wood.—The products obtained in the ordinary process of working, are acetic acid, wood spirit or methyl alcohol, acetone, pyroxanthine, xylite, lignine, paraflme, kerosene, or phenic acid, oxycenic acid, pitcairn, several homologues of benzole, with ammonia, and methylamine. There are also several other bodies of which the true nature is imperfectly known. The greater part of the above substances are fully described in separate articles in this work. See Acetic Acid, Paraffine, &c.

Peat appears to yield products almost identical with those from wood.

Destructive Distillation of Coal.—The number of substances yielded by the distillation of coal is astonishing. It is very remarkable that the fluid hydrocarbons produced at a low temperature are very different to those distilling when a more powerful heat is employed. The principal fluid hydrocarbons produced by the distillation and subsequent rectification of ordinary gas tar are benzole and its homologues. But if the distillate is procured at a low temperature as possible, or Boghead coal be employed, the naphtha is lighter, and the hydrocarbons which make its chief bulk belong to other series. See Naphtha.

3. Destructive Distillation of Animal Matters.—Bones are the principal animal substances distilled on the large scale. The naphthas which come over are exceedingly fetid, and are very troublesome to render clean enough for use. The products contained in bone oil will be described in the article Naphtha. Horn and wool have recently been examined with reference to the basic products yielded on distilling them with potash. Horn under these circumstances yields ammonia and amylamine. Wool I find to afford ammonia, pyrrol, butylamine, and amylamine. My experiments on feathers, made some years ago, although not carried so far as those on wool, appear to indicate a very similar decomposition.

The products yielded by animal matters, when distilled per se, are very different to those obtained when a powerful alkali is added previous to the application of heat. If feathers or wool be distilled alone, a disgustingy fetid gas is evolved containing a large quantity of sulphur. Part of the sulphur is in the state of sulphate of carbon. But if an alkali be added previous to the distillation, the sulphur is retained, and the odor evolved, although powerful, is by no means offensive. During the whole period of the distillation of ordinary organic matters containing nitrogen, pyrrol is given off, and may be recognized by the reaction afforded with a slip of deal wood dipped in hydrochloric acid. An interesting experiment, showing the formation of pyrrol from animal matters, may at any time be made with a lock of hair, or the feather of a quill. For this purpose the nitrogenous animal
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matter is to be placed at the bottom of a test tube, and a little filtering paper is to be placed half-way up the tube, to prevent the water formed during the experiment from returning and fracturing the glass. The end of the tube is now to be cautiously heated with a spirit lamp, and, as soon as a dark yellowish smoke is copiously evolved, a slip of deal previously moistened with concentrated hydrochloric acid is to be exposed to the vapor. In a few seconds the wood will acquire a deep crimson color. The fact of the presence of sulphur in wood, hair, or other albuminous compounds of that description, may be made very evident to an audience by the following experiment:—Dissolve the animal matter in very concentrated solution of potash in a silver or platinum basin, with the aid of heat. Evaporate to dryness, and raise the heat at the end to fuse the potash and destroy most of the organic matters. When cold, dissolve in water, and filter into a flask half full of distilled water. To the clear liquid add a little of Dr. Playfair’s nitroprusside of sodium; a magnificent purple tint will be immediately produced, indicative of the presence of sulphur. A very small quantity of hair or flannel will suffice to yield the reaction.

The above remarks on destructive distillation apply principally to highly complex bodies, the molecular constitution of which is either doubtful, as in the case of albuminous substances, or totally unknown, as with coals and shales. The destructive distillation of organic substances of comparatively simple constitution, such as acids and alkalies, sometimes yields products, the relation of which to the parent substance can be clearly made out. This holds more especially in the case of organic acids; the bases too often yield such complex results, that the decomposition cannot be expressed by an equation giving an account of all the products. We shall study a few cases separately.

4. Destructive Distillation of Acids.—The destructive distillation of acids takes place in a totally different manner, according as we have a base present or the operation is carried on without any addition. Many, if distilled per se, undergo a very simple reaction, consisting in the elimination of carbonic acid, and the formation of a pyroacid. But if an excess of base be present, the decomposition often results in the formation of a ketone, (see Acetone.) We shall offer a few examples of these decompositions. Gallic acid, heated to about 419 Fahr., is decomposed into pyrogallic and carboxylic acids, thus:—

\[
\text{C}_6\text{H}_4\text{O}_{10} = \text{C}_6\text{H}_4\text{O}_6 + 2\text{CO}_2
\]

Gallic acid. Pyrogallic acid.

There are cases in which the action of heat upon organic acids results in the formation of two substances, not produced simultaneously, but in two epochs or stages. In reactions like this, the first effect is the removal of two equivalents of carbonic acid, and by submitting the resulting acid to heat again, two more are separated. Under these circumstances, it is the second which is generally called the pyroacid. As an example we will take meconic acid, which breaks up in the manner seen in the annexed equations:—

\[
\begin{align*}
\text{C}_6\text{H}_4\text{O}_4 & = \text{C}_6\text{H}_4\text{O}_3 + 2\text{CO}_2 \\
\text{C}_6\text{H}_4\text{O}_3 & = \text{C}_6\text{H}_4\text{O}_2 + 2\text{CO}_2
\end{align*}
\]

Meconic acid. Comenic acid.

Pyrogallic acid.

It will be seen that the hydrogen remains unaffected. Perhaps the name pyrocomenic acid would be preferable to pyrocomenic acid, inasmuch as it is derived from comenic acid in the same manner as pyrogallic from gallic acid.

But pyroacids are not always derived from the parent acid by the mere elimination of carbonic acid; thus maleic acid, loses two equivalents of carbonic acid, and six equivalents of water, thus:—

\[
\text{C}_4\text{H}_4\text{O}_6 = \text{C}_4\text{H}_4\text{O}_4 + 2\text{CO}_2 + 6\text{H}_2\text{O}
\]

Maleic acid. Pyromaleic acid.

It does not invariably happen that the destructive distillation of acids per se results in the formation of a pyroacid; the destruction is sometimes more profound, the products being numerous and somewhat complex. Let us take as an illustration a case where all the results can be reduced to an equation. Oxalic acid, when heated in a retort without addition, yields water, oxide of carbon, carbonic and formic acids, in accordance with the annexed equation:—

\[
4(\text{C}_2\text{O}_4,\text{H}_2) = 4\text{CO}_2 + 2\text{CO} + 2\text{H}_2 + \text{C}_2\text{H}_4\text{O}_4
\]

Oxalic acid. Formic acid.

The admixture of sand, pulverized pumice stone, or any other inert substance in a state of fine division, often remarkably assists in rendering the decomposition more easy and definite. Thus, if pure sand be mixed with oxalic acid, the quantity of formic acid is so increased, that the process is sometimes employed in the laboratory as a means of affording a pure and tolerably strong acid.

We have said that the destructive distillation of acids proceeds in a very different manner according as we operate upon the acid itself, or a salt of the acid. The distillation of

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the pure salt yields different products to those which are obtained when the salt or dry acid is mixed with a large excess of a dry base, (such as quicklime,) before the application of heat. If, in the former mode of processing, two atoms of the acid are decomposed, yielding a body containing the elements of two atoms of carbonic acid and two of water less than the parent acid, such body is called a ketone. Thus when two atoms of acetate of lime are distilled, the products are one atom of acetone, and two of carbonic acid. Of course the carbonic acid combines with the lime, thus:

$$2(C\text{H}_4\text{O}_4) = C\text{H}_4\text{O}_3 + 2(CaO,CO)$$

Acetate of lime. Acetone.

If, however, the salt is not of a very low atomic weight, and the quantities operated on are at all considerable, secondary products are formed, as in the dry distillation of butyrate of lime, when, if the substance is not in very small quantity, carbon is deposited, and a certain quantity of butyral (C\text{H}_4\text{O}) is formed, and probably other substances.

As an illustration of the decomposition undergone when acids are distilled with a great excess of dry base, we shall select that of benzoic acid, which under the circumstances alluded to yields benzole and carbonate of the base.

$$C\text{H}_4\text{O}_4 = C\text{H}_4\text{O} + 2(CO)$$

Benzole acid. Benzole.

5. Destructive Distillation of Bases.—It has been found that the organic bases undergo a much simpler and more direct decomposition when subjected to destructive distillation in presence of alcalies than when they are exposed to heat without admixture. There are two bodies almost invariably found among the resulting products, namely, ammonia and pyrrol. In this respect, therefore, the organic alcalies behave like other nitrogenized animal and vegetable products. The decomposition is almost always rather complex, and it is very rare that the products are sufficiently definite to be arranged in the form of an equation. The most common substances found, are the alcohol bases, and these are almost invariably of low atomic weight. One great difficulty connected with researches on this subject, is owing to the fact of its being seldom that the products are in sufficient quantity to enable a thorough knowledge of the molecular constitution to be arrived at. Unfortunately this information is much wanted in consequence of the numerous cases of isomerism to be met with among the alcohol bases. See Formule, Chemical. Thus it is difficult, when working on very small quantities, to distinguish between dimethylamine and ethylamine, both of which have the formula C\text{H}_3\text{N}.

It is remarkable that there is a great similarity between the products of the destructive distillation of some of the most unlike nitrogenous substances. This is incomparably seen in the case of bones, or rather the gelatinous tissue of bones, shale and coal naphthas, and cinchonine. An inspection of the following table, compiled from a paper, (by the writer of this article,) "On some of the Basic Constituents of Coal Naphtha," will render this evident.

<table>
<thead>
<tr>
<th>Gelatinous Tissue</th>
<th>Shale Naphtha</th>
<th>Coal Naphtha</th>
<th>Cinchonine</th>
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</thead>
<tbody>
<tr>
<td>-</td>
<td>Parvolline.</td>
<td></td>
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<td>-</td>
<td></td>
<td>Chinoline.</td>
<td>Chinoline.</td>
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<td>-</td>
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<td>Lepidine.</td>
<td>Lepidine.</td>
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<td>-</td>
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<td>Cryptidine.</td>
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</tr>
<tr>
<td>Aniline.</td>
<td></td>
<td>Aniline.</td>
<td></td>
</tr>
</tbody>
</table>

It is very possible that some of the above bases, having the same formula, but derived from different sources, will, in the course of time, prove to be merely isomeric, and not absolutely identical. The author of this article has quite recently found that the chinoline of coal tar is certainly not identical with that from cinchonine. The base from the latter source yields a magnificent and fast blue dye upon silk, when treated by a process which gives no reaction if the coal base be substituted. It is unfortunate that the reaction is with the latter instead of the former, as it would have added one more to the list of gorgeous dyeing materials yielded by coal tar.

6. General Remarks.—The tendency of numerous researches, made during the last few years, has been to show that there is no organic substance, capable of resisting high temperatures, which may not be found to exist among products of destructive distillation. By varying the nature of the substance to be distilled, and also the circumstances under which the operation is conducted, we can obtain an almost infinite variety of products. Acids, bases, and neutral substances, solid, liquid, and fluid hydrocarbons, organic positive, nega-
tire, and derived radicals, organo-metallic bodies,—all may be produced by the action of high temperatures on more or less complicated bodies. Much has already been done, but the facts at present accumulated relate merely to the superficial and more salient substances. On penetrating further below the surface, far more valuable and interesting facts will come to light.—C. G. W.

DIVING-BELL. As it is frequently desirable to raise objects from the bottom of the sea or rivers, and to lay the foundation of piers and similar structures, some contrivance was devised to enable man to descend below the water, and to sustain himself while there. The first method adopted was the very simple one of letting down a heavily weighted bell vertically into the water. As the bell descended, the air got over pressed, and the water rose in the bell, but never to the top, and within that space the man was sustained for some time. The air, however, was vitiated by the processes of respiration, and the man had to be drawn up. It is curious to find that as early as 1693 a very complete system of diving without a bell was devised, as the following quotation will show:—

A. D. 1693. "William and Mary, by the Grace, &c. &c. Whereas John Stapleton, gentleman, hath by his great study and experiment invented a new and extraordinary engine of copper, iron, or other metal, with glasses for light joints, and so contrived as to permit a person enclosed to move and walk freely with under water, and yet so closely covered over with leather as sufficiently to defend him from all the jumps of it. Also invented a way to force air into any depth of water, whereby the person in the aforesaid engine may be supplied with a continual current of fresh air, which not only serves him for respiration, but may also be useful for continuing a lamp burning which he may carry about with him in his hand. * * * Likewise a way to make the same again serviceable for respiration, and by continually repeating the operation, a man may remain a long time under water, in either of the said engines, without any other air than the said engines do contain, whereby he shall be preserved from suffocation, if any extraordinary accident should interrupt the current of fresh air afore mentioned."—Letters Patent. Rolls Chapel. Edited by Bennet Woodcroft.

The defects were many in this apparatus, and Dr. Halley invented a bell the object of which was to remedy this.

Dr. Halley's bell was of wood coated with lead, and having strong glass windows above, to allow the passage of light to the diver. In order to supply air, a barrel was taken with an open hole in the bottom, and a weighted hose hanging by, and fitting into a hole at the top. From this barrel the air of the bell was supplied as frequently as it became vitiated, the barrels of air being sent down from above. Spalding improved upon Halley's bell, and again Friewald made some improvements on Spalding's, but in principle these bells were all alike. The modern bells are usually large and strong iron bells, with windows in the upper part. By means of an air-pump, placed on the surface, air is sent down to the divers in the bell, and the vitiated air is as regularly removed from the bell by other tubes through which it escapes. These diving-bells are lowered by means of cranes, and are moved about in the water by those above, signals being given by the men below. The difficulty of moving this machine renders it still inconvenient, and recent attempts have been made to obviate this, by the construction of diving-bell upon principles entirely different. This new diving-bell, to which the name of the Näutilis has been applied, has proved so useful in the construction of some parts of the Victoria Docks, and some works on the Seine, that a full description of it is appended.

The Näutilis machine is entirely independent of suspension; its movements are entirely dependent on the will of those within it, and without reference to those who may be stationed without; it possesses the power of lifting large weights, per se, and at the same time is perfectly safe, by common care in its operations. This latter is the greatest desideratum of all. These advantages must strike all as combining those requisites of success which have been always wanting in the present known means for constructing works under water.

The form of the machine is not arbitrary, but depends entirely on the nature of the work to be performed, adapting itself to the various circumstances attending any given position. By reference to the annexed figures, it will be perceived that when at rest, being entirely enclosed, its displacement of water being greater than its own weight, it must float to the surface, (see fig. 241.) Entering through a man-hole at the top, (which is closed either from the inside or outside,) you descend into the interior of the machine, portions of which are walled off on either side, forming chambers; these chambers are connected at or near the bottom of a pipe a, which opens by a cock b, outwards to the external surrounding water. An opening in the bottom of the machine of variable dimensions is closed by a door or doors susceptible of being opened or closed at pleasure. The chambers w w are likewise connected at top by a smaller pipe c, which opens through the top of the machine, and to which opening is affixed a flexible pipe, with coils of wire spirally enclosed. Branches on this latter pipe t allow also communication with the larger or working chamber.

At the surface of the water placed on a float or vessel for the purpose, is a receiver of
variable dimensions, to which is attached at one end a hollow drum or reel, to the barrel of which is affixed the other end of the flexible pipe $a$, leading to the top of the nautilus. At the other end of, and in connection with the receiver, is a powerful air-condensing pump. This combination represents the nautilus as adapted to engineering work.

As to the *modus operandi*:- The operator with his assistants enters the machine through the top, which is then closed. To descend, the water-cock $b$ is opened, and the external water flows into the chambers $w$; at the same time a cock, on a pipe opening from the chambers outwards, is opened, in order that, the air escaping, an uninterrupted flow of water may take place into the chambers. The weight of water entering the chambers causes a destruction of the buoyancy of the machine, and the nautilus gradually sinks. As soon as it is fairly under water, in order that the descent may be quiet and without shock, the water-cock $b$ is closed. The receiver at the surface being previously charged by the air-pump to a density somewhat greater than that of the water at the depth proposed to attain, one of the branch-cocks on the pipe $c$, connecting the chambers at top, is opened, and the air rushes into the working chamber, gradually condensing until a density equal to the density of the water without is attained; this is indicated by proper air and water gauges.
These gauges marking equal points, showing the equilibrium of forces without and within, the cover to the bottom is removed or raised, and communication is made with the underwater surface, on which the nautilus is resting. In order to move about in localities where tides or currents do not affect operations, it is only necessary for the workman to step out of the bottom of the nautilus, and placing the hands against its sides, the operator may move it (by pushing) in any direction.

Where currents or tides, however, have sway, it becomes necessary to depend upon fixed points from which movements may be made in any direction. This is accomplished by placing, in the bottom of the nautilus, stuffing-boxes of peculiar construction, (XV. fig. 242,) through which cables may pass over pulleys to the external sides, thence up through tubes, (to prevent their being worn,) to and over oscillating or swinging pulleys, placed in the plane of the centre of gravity of the nautilus, and thence to the points of attachment respectively, (fig. 243.) The object to be gained by having the swinging pulleys in the plane of the centre of gravity of the mass, is to hold the machine steady and to prevent oscillation. Within the machine, and directly over the above stuffing-boxes, are windlasses for winding in the cables. By working these windlasses movement may be effected, and of course the number of these cables will depend on the variable character of the situation to be occupied. Having thus secured the means of descending, communicating with the bottom, and of movement, the next point is to ascend. Weight of water has caused a destruction of buoyancy at first, and consequent shaking; if, then, any portion of this water is removed, an upward effort will at once be exerted exactly proportionate to the weight of water thrown off. The air in the receiver at the surface being constantly maintained at a higher density than that of the water below, if we open the water-cock on the top pipe C C, throwing the condensed air from the receiver above directly on to the surface of the water in the chambers, movement and consequent expulsion of the water must take place, and an upward movement of the machine itself, which will rise to the surface.

It is evident that if, previously to the expulsion of the water, the nautilus be affixed to any object below, the power exerted on that object will be exactly proportionate to the weight of water expelled, and the power will continue increasing, until there being no further weight to be thrown off, the maximum effect is produced. To apply this power to lifting masses of stone or rock, proper arrangements are affixed to the centre of the opening in the bottom, by which connection can be made with the weight, admitting, at the same time, the swinging around of the object suspended, so that it may be placed in any required position. In the construction of permanent work, or the movement of objects whose weight is known, or can be estimated, a water, or so-called lifting tube, is placed on the side of the water chamber, which indicates the lifting power exercised by the nautilus at any moment. The advantage of this gauge will be recognized, insomuch as without it the closest attention of the operator, working very cautiously, would be necessary to determine when the weight was overcome; by its aid, however, the operator boldly throws open all the valves necessary to develop the power of the nautilus, watching only the gauge. The water, having reached the proper level indicating the required lifting power, he knows the weight must be overcome, or so nearly so that the valve or cocks may be at once closed, in order that the movement may take place horizontally. A moment's reflection will show that, if
there were not an index of this character, carelessness or inattention on the part of the operator, by leaving the cocks open too long, might develop a power greater than required, and the nautilus would start suddenly upward. The expansive power of air, acting upon the incompressible fluid, water, through the opening in the bottom, gives a momentum which, by successive developments of expansion in the working chamber, is constantly increasing in velocity, until, in any considerable depth of water, the result would be undoubtedly of a very serious character. Take, for exemplification, the nautilus in thirty-three feet of water, and bottom covers removed, and an equilibrium, at fifteen pounds to the inch, existing between the air and the water at the level of the bottom of the machine. Upward movement is communicated the instant the machine rises in the slightest degree, the existing equilibrium is destroyed, and the highly elastic qualities of air assume preponderance, exerting, from the rigid surface of the water below, an impulsive effort upward in the direction of least resistance. At each successive moment of upward movement the impelling power increases, owing to the increasing disparity between the pressure of air within struggling for escape. The machine, thus situated, becomes a marine rocket, (in reality,) in which the propelling power is exhausted only when the surface is reached, and a new equilibrium is obtained. It will readily be seen that, were this difficulty not overcome, it would be impossible to govern the nautilus; for, rising with great velocity to the surface, the machine is carried above its ordinary flotation, or water line, a little more air escaping owing to the diminished resistance as that level is passed; the reed, or surging downwards, causes a condensation of the air remaining in the chamber; a portion of the space previously occupied by air is assumed by water; the buoyant power becomes less, the machine settles slightly more by condensation of the air, a larger space is occupied by water, and the nautilus redescends to the bottom with a constantly accelerating movement, seriously inconveniencing the operator by filling more or less with water, according to depth. For many months the difficulties just enumerated baffled all attempts at control. A weight attached could be lifted, but the instant it was entirely suspended,—before the valves could be closed,—upward movement was communicated beyond control. This difficulty, so fatal, has been overcome by an arrangement at the bottom of the nautilus, with channels which radiate from the opening in an inclined direction, debouching at the sides of the machine. The moment, then, that the air, by its expansion from diminished resistance, or by the introduction from above of a greater volume than can be sustained by the water below, reaches, in its downward passage, the level of these chambers, following the direction of
Diving Bell.

least resistance, it passes through these channels and escapes into the surrounding water, without of course affecting the movement of the machine in the least.

The pump for supplying air to the diving-bell or other suitable vessel, is represented at figs. 244 and 245, and is constructed as follows:—a is a cylinder, opening at the upper part into a chamber or chambers R R, separated by a partition k. On the side of each of these chambers there is a valve n n, opening inwards, and at the upper part of the same are two valves m m, opening outwards into the valve chamber a. Outside the opening for each of the valves n n, there is a cup, into which the end of the water supply pipe w passes; by this means a small stream of water is supplied to the cup, and is drawn from it into the chamber r to supply the waste in the operation of pumping. The valve chamber a is covered with a jacket k, having a space between it and the valve chamber that is filled with water from the water pipe x, which affords a stream of cold water to carry off the heat from the condensed air which is forced into the chamber. The water thus supplied circulates through the tubes in the chamber and round them in the jacket, and thus cools the air in these tubes; it is then conveyed so as to be usefully employed in a steam-boiler, or is allowed to run off. The air and a small quantity of water is forced up from the cylinder a by the stroke of the piston c into the chamber r, which is thereby filled with water, and thus the air is expelled therefrom, a small quantity of the water passing with it and covering the valves, by which means they are kept tight and wet. The air and water thus discharged, after passing around the small tubes in the valve chamber and being cooled, are forced outward and conveyed to the condenser. On the return stroke of the piston, the other chamber r is filled, and air and water expelled from it in like manner through its valve into the valve chamber. There is always a sufficient quantity of water in the cylinder a and chamber r to fill the latter when the water is all expelled from the cylinder, by the piston c having been driven to one end of it, and when the piston returns to the opposite end of the cylinder, the water flows in behind it, and draws in its equivalent in bulk of air and water through the valve n. On its return, this is forced out through the valve k into the chamber r, as mentioned above. The water being non-elastic, if the parts are kept cool enough to avoid raising steam, this process may be continued for any length of time. A transverse section of this apparatus is shown in fig. 245.

Figs. 246 and 247 represent the speaking-tube and alarm-bell above referred to. The construction of this mechanism is as follows:—There is a hollow casting, one portion of which is triangular in form, from one end of which a short tube a projects. This tube a has a screw cut on it, and a projecting flange at its junction with the triangle. This is screwed into the top of the diving vessel or armor from the inside, and projects through
it to allow the coupling of a flexible or other hose to be attached to it. At the opposite angle, and in a line with $s$, there is a tubular projection $h$, provided with a screw to receive a cap $f$, to which is to be attached a piece of hose. Within the tube $f$, and at its junction with $h$, is placed a thin diaphragm of metal or other suitable material $c$, for which purpose, however, a thin silver plate that just fits the bore of the cap $f$ is preferred. This diaphragm closes all communication between the diving vessel and the external air. By this means it is easy to converse through any required length of tubing. It may be desirable to fit a stop-cock into the tubular projection $h$, as a precautionary means of preventing the escape of air in the event of a rupture of the diaphragm. The upper part of the triangular enlargement of the speaking-tube is tapped for a stuffing-box at $g$, within which there is an axis $h$, which runs from side to side of the said enlargement, and through the stuffing-box at one side. On this axis $h$ is fixed a lever $i$ within the said enlargement, which lever communicates with the surface of the water by means of a wire fixed at its reversed end, and running through the whole length of pipe. On the outer extremity of the axis $h$ is affixed a hammer, which strikes on a bell $k$ connected to the tube, as shown in the drawing. By this means the attention of the operator below may be drawn to the speaking-tube when it is required to converse with him from the surface of the water, and the men whose duty it is to attend to the operator below can, by placing their ear at the end of the tube, hear the bell struck below as a signal for communication with them at the surface.

The only parts of the apparatus not yet described, are the saw for cutting the tops of piles to an uniform level, the pump which enables the divers themselves to rise to the surface in the event of the flexible hose being detached or injured, and the contrivance for screwing an eye-bolt into the side of the sunken vessels.

The arrangement of the saw-frame and connections are shown in fig. 248. Only as much of the bottom of the nautilus is shown as will render the position of the saw understood. $p$ is a pile which is required to be cut down to the same level as the others; $n$ is the blade of the saw; $v$ the framing by which it is stretched; $c, n$, the handle which rests on the cross-bars; $s$, which is attached to the upright part of the handle which is laid hold of by the workman inside when working the saw. $n, a, r$, a bent lever with two friction rollers at $r$ which guides the saw forwards while making the cut.

The pump for ascending in ease of accident to the air-hose, is not shown in the drawing. It is a simple force-pump placed in the working chamber, by which the ballast water in $w$, (fig. 242,) can be pumped out so as to lighten the apparatus sufficiently to allow of its ascent.

The apparatus for fixing the eye-bolts is shown in fig. 249. The operation of this apparatus is as follows:—It will be observed the chamber $n$ opens outwards to the water, so that when the sliding partition or valve $y$ is forced down by the lever $g$, the communication of the water with the chamber $c$ is cut off. The lid $z$ being removed, a bolt $i$ (or other operating tool or instrument) is placed within the chamber $c$; the rod $k$ is forced through the stuffing-box $l$, until the recessed end of the rod contains the end of the bolt; the small rod $j$ is then screwed through the stuffing-box $m$, until the screw on the end of this rod has become affixed to the end of the bolt contained within the recess at $p$. The lid $z$ of the chest is then fastened on, and the partition or valve $y$ raised, the stuffing-box $m$ preventing the escape of air. Communication is thus opened between the chambers $a$ and $v$, the latter being open outwards. The
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rod \( k \) is now pushed outwards by pressing on the handle \( l \) through the stuffing-box \( l \), until the vessel or object to be operated upon is reached, when the operation is performed as required. It will be observed that the stuffing-box prevents the escape of air out of the bell or the admission of water into it, the stuffing-box \( n \) having the same tendency. After the operation with the tool or instrument is complete, the rod \( k \) is disconnected by unscrewing the rod \( k \), and is drawn into the chamber \( \lambda \) by means of the handle \( h \); the partition or valve \( y \) is again lowered, and the operations above described are repeated. It will hence be obvious that a number of eye-bolts might in this manner be successfully inserted in the side of a sunken vessel from the diving-belt, so that by hooking on the "canoes," the strain would be so distributed as to prevent injury by the process of lifting the said vessel.

**DOLOMITE.** Magnesian Limestone. This rock occurs in very great abundance in various parts of England, especially in Yorkshire, Nottinghamshire, and Somerset. It is largely employed as a building stone.

Karsten infers, from his numerous analyses of dolomite, that in those which are crystallized, the carbonate of lime is always combined in similar equivalent proportion with another carbonate, which may be carbonate of magnesia alone, or together with carbonates of iron or manganese, and sometimes both. In the uncrystallized varieties of dolomite, the diversity in the proportion of lime and magnesia is indefinite, but such masses must be regarded as mere mixtures of true dolomite and carbonate of lime. Acids do not produce a perceptible effervescence with dolomite, except when digested with it in fine powder. Karsten found that dilute acetic acid extracts from dolomites, at a temperature below 32° Fahr., only carbonate of lime, while a dolomite mass remains undissolved. Hence he regards them as mixtures of dolomite with unaltered carbonate of lime.—*Bachofen*.

Sulphate of magnesia has been manufactured from dolomite on the large scale.

Dr. William Henry, of Manchester, patented a process of the following kind:—Calcine magnesian limestone so as to expel the carbonic acid; then convert the caustic lime and magnesia into hydrates by moistening them with water; afterwards add a sufficient quantity of hydrochloric, nitric, or acetic acid, or chlorine to dissolve the lime, but not the magnesia, which, after being washed, is converted into sulphate by sulphuric acid, or, where the cost is objectionable, by sulphate of iron, which is easily decomposed by magnesia. Or the mixed hydrates of lime and magnesia are to be added to bittern; chloride of calcium is formed in solution, while two portions of magnesia (one from the bittern, the other from the magnesia) are left unchanged. Hydrochlorate of ammonia may be used instead of bittern; by the reaction of this on the hydrated magnesian lime, chloride of calcium and carbonate of ammonia remain in solution, while magnesia is left undissolved; the ammonia is separated from the decanted liquor by distillation.

In some chemical works on the Tyne, the dolomites from the coast around Marsden are treated with sulphuric acid, and the sulphate of magnesia (*Epson salts*) separated from the sulphate of lime by crystallization.

The dolomite has also been employed by the late Hugh Lee Pattinson for the manufacture of the CARBONATE OF MAGNESIA.

**DOWN.** See FEATHERS. Down imported in 1857, 5,908 lbs.

**DRAGON'S BLOOD.** Pereira enumerates the following varieties of this substance found in commerce:—

1. Dragon's blood in the red; Dragon's blood in sticks; Sanguis Draconis in baculis.
2. Dragon's blood in oval masses; Dragon's blood in drops; Sanguis Draconis in lachrymis.
3. Dragon's blood in powder.
4. Dragon's blood in the tour; Sanguis Draconis in granis.
5. Lump Dragon's blood; Sanguis Draconis in musis.

Besides these, there are Dragon's blood in cakes, and False Dragon's blood, in oval masses.

**DRAINING TILES.** Burnt-clay tiles, generally shaped in section like a horse shoe, about one foot long and two or three inches broad. These are much used in agricultural draining.

**DRY GRINDING.** The practice of employing dry stones has been long adopted for the purpose of quickening the processes of sharpening and polishing steel goods. The dry dust from the sand-stone, mixed with the fine particles of steel, being inhaled by the workmen, produces diseases of the pulmonary organs to such an extent, that needle and fork grinders are reported rarely to live beyond the ages of twenty-five or thirty.

Mr. Abraham, of Sheffield, first invented magnetic guards, which, being placed close to the grindstone, attracted the particles of steel, and thus protected the men from their influences. Still they suffered from the effects of the fine sand-dust, and the grinders heedlessly abandoned the use of them altogether.

Mr. Abraham devised another plan, which is employed, although only partially, in the
DULSE. The Rhodomenia palmata. See Algæ.

DUNES. Low hills of blown sand, which are seen on the coasts of Cheshire and Cornwall, in this country, and also in many places skirting the shores of Holland and Spain.

DUTCH LEAF or FOIL, a composition of copper and lime, or of bronze and copper leaf. See ALLOYS, Brass, and BRONZE POWDERS.

DUTCH RUSH. Equisetum Hyemale. This rush is known also as the Large branchless Horse-tail. The dried stems are much employed for polishing wood and metal. For this purpose they are generally imported from Holland.

DYING. The relations of dying with the principles of chemistry, constitute the theory of the art, properly speaking; this theory has for its basis the knowledge—

1st. Of the nature and properties of the bodies which dyeing processes bring into contact,

2d. Of the circumstances in which these bodies are brought together, facilitating or retarding their action.

3d. The phenomena which appear during their action; and

4th. Properties of the colored combinations which are produced.

The first of these generalities embraces a knowledge of the preparations which stuff necessarily undergoes previous to dyeing, and also the preparations of the dye-drug before bringing it into contact with the stuff.

The operations to which stuffs are subjected before dyeing, are intended to separate from them any foreign matters which may have become attached, or are naturally inherent in the stuff. The former are such as have been added in the spinning, weaving, or other manipulations of the manufacture, and are all removed by steeping in an alkaline lye and washing. The second are the natural yellow coloring substances which coat some of the various fibres, both vegetable and animal; and the chlorophylle, or leaf-green of vegetables. The removal of these is generally effected by boiling in soap and alkaline lyes. A weak bath of soda, in which the stuff is allowed to steep for some time, and then washed in water, is generally the only preparation required for wool, in order that it may take on a uniform dye.

To remove the gummy or resinous matter from silk, it requires boiling in soap lye; however, its removal is not essential to the stuff combining with the dye, as silk is often dyed while the gum remains in it, in which case it is only rinsed in soap lye at a very moderate heat, to remove any foreign matters imbibed in the process of manufacture.

Vegetable fibre, as cotton, has such natural resinous matters that retard the reception of the dye removed by boiling, either with or without alkaline lyes; but the natural dun color of the fibre is not removed, which from the laws of light and color already referred to, would interfere with the production of bright light tints; under these circumstances, the natural color of the fibre has to be previously removed by bleaching, for which see the article, BLEACHING.

The necessary preparation of the dye-drugs within the province of the dyer, is to obtain the color in a state of solution, so as to allow the fibre to absorb it, and to produce chemical combination, or to get the dye or color in such a minute state of division as it will penetrate or enter into the fibre of the stuff. These preparations embrace the formation of decoctions, extracts, and solutions, and also in some cases of precipitation, previous to immersing the stuff into the bath. Stuffs, chemically considered, have but a feeble attraction for other matters, so as to combine with them chemically; still, that they possess certain attractions is evident from various phenomena observed in the dyeing processes, and that this attraction is possessed with different degrees of intensity by the different fibres, is also evident from the case and permanence that woollen stuff will take up and retain dyes compared with cotton; and also, that certain dyes are retained and fixed within or upon one kind of fibre and not at all in another. This may be determined by plunging the dry stuff into solutions of the salts, and determining the density of the solution before the immersion and after withdrawing the stuff. Wool abstracts alum from its solution, but it gives it all out again to boiling water. The sulphates of iron, copper, and zinc resemble alum in this respect. Silk steeps for some time in a solution of protosulphate of iron, abstracts the oxide, and thereby the dyed, and leaves the solution achromatic. Cotton in solution of iron produces the same effect. Wool put in contact with cream of tartar, decomposes a portion of it; it absorbs the acid within its pores, and leaves a neutral salt in solution in the liquor.
DYEING.

Cotton produces no such effect with tartar, showing by these different effects that there are certain attractions between the stuff and dyes. This attraction, however, may be more what is termed a catalytic influence, the fibres of the stuff producing a chemical action with the salt or dye with which it is in contact. This attraction or affinity of the fibre for the dye-drag does not produce a very extensive effect in the processes of dyeing. More probably the power of imbibing and retaining colors possessed by the fibre is more dependent upon a mechanical than a chemical influence.

All dye-drag must in the first instance be brought into a state of solution, in order that the dye may be imbibed by the fibre; but if the fibre exerts no attraction for the color so as to retain it, it is evident as long as it remains capable of dissolving in water, the stuff being brought into contact with water will soon lose their color. A color thus formed does not constitute a dye, however strongly stained the stuffs may appear to be, in or out the dyeing solution; in order to form a dye, the color must be fixed upon or within the stuff in a condition insoluble in water. Hence the mere immersion of the stuff into a solution of a color will not constitute a dye, except where the stuff really has an attraction for the color and retains it, or causes a decomposition by which an insoluble compound is fixed upon it, such as referred to by putting stuffs into solutions of iron. The abstraction of the color from a solution by the immersion of the stuff, is often the result of a mechanical attraction possessed by porous substances, enabling them to absorb or imbib all certain coloring matters from solutions that are held by a weak attraction by their solvents. On this principle, a decoction of cochineal, logwood, brazil-wood, or a solution of sulphate of indigo, by digestion with powdered bone black, lose their color, in consequence of the coloring particles combining by a kind of capillary attraction with the porous carbon, without undergoing any change. The same thing happens when well scoured wool is steeped in such colored liquids; and the color which the wool assumes by its attraction for the dye is, with regard to most of the above colored solutions, but feeble and fugitive, since the dye may be again abstracted by copious washing with simple water, whose attractive force, therefore, overcomes that of the wool. The aid of a high temperature, indeed, is requisite for the abstraction of the color from the wool and the bone-black, probably by enlarging the size of the pores, and increasing the solvent power of the water.

Those dyes, whose coloring matter is of the nature of extractive, form a faster combination with stuffs. Thus the yellow, fawn, and brown dyes, which contain tannin and extractive, become oxygenated by contact of air, and insoluble in water; by which means they can impart a durable dye. When wool is impregnated with decoctions of that kind, its pores get charged by capillarity, and when the liquid becomes oxygenated, they remain filled with a color now become insoluble in water. The fixation of iron oxide and several other bases also depends on the same change within the pores of fibre; hence all salts that have a tendency to pass readily into the basic state are peculiarly adapted to act as a medium for fixing dyes; however, this property is not essential.

In order to impart to the stuffs the power of fixing the color in an insoluble form upon it, recourse is had to other substances, which will combine with the soluble and form with it an insoluble color; and it is not necessary that this new substance should have an attraction for the stuff, or be capable of passing into a basic form, any more than the original color, but it is necessary that it be rendered insoluble while in contact with the stuff.

Such substances used to unite the color with the stuff have been termed mordants, which meant that they had a mutual attraction for the stuff and color; and combining with the stuff first, they afterwards took up the color; but this is only so in some instances. A few examples will illustrate the bearing of these mordants. If a piece of cotton stuff is put into a decoction of logwood, it will get stained of a depth according to the color of the solution, but this stain or color may be washed from the cotton by putting it into pure water, the color being soluble. If another piece of cotton stuff be put into a solution of protosulphate of iron, and then washed from this, a portion of the iron will have undergone oxidation, and left the acid, and become fixed upon the fibre and insoluble in water. Whether this oxidation is the result of an influence of the stuff, or the effect of the oxygen of the air and water in which the goods are exposed, it does not matter meantime, only this fixed oxide constitutes an example of a mordant by its combining with the stuff. If this stuff is now put into a decoction of logwood, the coloring matter of the logwood will combine with the oxide of iron fixed upon the fibre, and form an insoluble color, which after washing will not remove from the stuff. If, instead of washing the stuff from the sulphate of iron solution in water, it be passed through an alkaline lye of soda or potash, the acid holding the iron in solution is taken hold of by the alkali, and removed. The oxide of iron is thus left upon the stuff, in a much larger quantity than in the former case, and as firmly fixed, although not by any attraction between it and the fibre, but simply being left with it. And this stuff being now put into the logwood liquor, will form a dye of a depth according to the quantity of iron thus fixed upon the stuff, and equally permanent with that which had been fixed on the stuff by the oxidation in working.
DYEING.

Such, then, are the methods of fixing within the stuff insoluble colors from soluble compounds, and from these remarks the necessity of having the dye in solution will also be evident.

Suppose, again, that the sulphate of iron be mixed with the logwood decoction, there will be produced the same color or dye as an insoluble precipitate: if the cotton stuff is put into this, no color worthy of the name of a dye will be obtained, as the cotton will not imbibe within its fibre this precipitate. Place woollen stuff in the same liquid, there is formed a very good dye, the woollen fibre having obtained a great portion of the solid precipitate, probably owing to woollen fibres being much larger than those of cotton. Thus, with cotton and other stuff that will not imbibe freely solid precipitates, the mordant must be fixed within the fibre previous to applying the coloring substances, such as the vegetable decoctions. It will also be seen that the dye which is the product of combination between the mordant and color is not that of the natural color of the drug, but the color of the compound. Hence the great variety of tints capable of being produced from one dye-drug, by varying the kind or intensity of the mordant. So that in the above instances, it is not the color of the hematoxylin fixed on the stuff, but its compound with iron, or tin, or alumina, as the case may be, of which there is always a different tint.

It is upon this principle of rendering bases insoluble within the fibre by chemical means, that has brought to the use of the dyer a great number of mineral dyes which in themselves, whether separate or combined, have no attraction whatever for the fibre; such as solutions of sulphate of copper, and yellow prussiate of potash, nitrate of lead, and bichromate of potash, &c. Suppose the stuff to be dyed a yellow by the two last-named salts, was first put into the solution of lead and then washed previous to being put into the bichromate solution, the greater portion of the lead would be dissolved from the stuff, and a very weak yellow would be obtained. If the stuff from the lead solution was put directly into the bichromate solution, a very good dye would be the result; but the portion of the solution remaining upon the surface of the stuff will combine with the chrome and form a precipitate which the fibre cannot imbibe, but will form an external crust or pigment upon the surface, which blocks up the pores, and exhausts to no purpose the dye, causing great waste; hence the stuff from the solution of lead is put into water containing a little soda or lime, and the lead is thus reduced to an insoluble oxide within the fibre. The goods may now be washed from any loose oxide adhering, and then passed through the bichromate solution, when the chromic acid combines with the oxide of lead, forming a permanent yellow dye. Thus it will be seen that whether the combination of the color with the stuff be chemical or mechanical, the production of the dye which is fixed upon the fibre is certainly a chemical question, and the dyer should be familiar with the nature and principles of these reactions.

There are a few instances where the dye produced does not come within the sphere of these principles, there being no mordants required, nor any combination of the color formed within the stuff, but the dye-drug in its natural hue is fixed within the fibre. Such colors have been termed substantives, to distinguish them from those produced by means of mordants, which are termed adjective. Amongst this class of dyes and dyeing drugs stands pre-eminent indigo-blue. Indigo in its natural state is entirely insoluble in water, and is of a deep blue color. The composition of this blue indigo is represented as—

| Carbon | - | - | - | 16 | Nitrogen | - | - | - | 1 |
| Hydrogen | - | - | - | 5 | Oxygen | - | - | - | 2 |

But it is found capable of parting with a portion of the oxygen, and by so doing, losing entirely its blue color; and in this deoxidized condition it is soluble in alkaline lyes and lime water; this colorless compound is termed indigogene. The opinion of Liebig upon the constitution of this substance is, that indigo contains a salt radical, which he terms Anyle, composed of C$_3$H$_5$N. He considers that indigogene or white indigo is the hydrated protoxide of this radical, and that blue indigo is the peroxide, represented thus:—

<table>
<thead>
<tr>
<th>C</th>
<th>H</th>
<th>N</th>
<th>O</th>
<th>Water.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt radical, anyle</td>
<td>16</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Indigogene</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Blue indigo</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Advantage is taken of this property of indigo, of parting with its oxygen and becoming soluble, to apply it to dyeing, and it is effected by the following means, when for the purpose of dyeing vegetable stuff, as cotton; and from the circumstance of these operations being done cold, the method is termed the cold vat, which is made up as follows:—The indigo is reduced to an impalpable pulp, by being ground in water to the consistence of thick cream. This is put into a suitable vessel filled with water, along with a quantity of coppers and newly skinned lime, and the whole well mixed by stirring. After a short time the indigo is deoxidized and rendered soluble by a portion of the lime which is added in excess, the reaction being represented thus:—
DYING.

1. Indigo, composed of
   - Indigene
   - Oxygen
   Dyeing Solution.

2. Copperas
   - Protoxide of Iron
   - Protoxide of Iron
   - Sulphuric Acid
   Peroxide of Iron.

3. Lime
   - Lime
   - Lime
   - Lime
   Sulphate of Lime.

The peroxide of iron and sulphate of lime are precipitated to the bottom, and the indigene and lime form a solution of a straw color, with dark veins through it.

The operation of dyeing by this solution is simply immersion, technically, dipping. The stuff by immersion imbues the solution, and when taken out and exposed to the air, the indigene upon and within the fibre rapidly takes oxygen from the atmosphere, and becomes indigo blue, thus forming a permanent dye, without any necessary attraction between the indigo and the stuff.

The indigo vat for wool and silk is made up with indigo pulp, potash, madder, and bran. In this vat the extracts of madder and bran perform the deoxidizing functions of the copperas in the cold vat, by undergoing a species of fermentation.

Pastel and wood, either alone or with the addition of a little indigo, are also used for the dyeing of wool and silk stuff; the deoxidation being effected by the addition of bran, madder, and weld. In dyeing with these vats, the liquor is made warm, and they require much skill and experience to manage, in consequence of their complexity, being always liable to go out of condition, as the dyeing goes on, by the extraction of the indigene and the modification of the fermentable matter employed to deoxidize the indigo to supply that loss. The alkaline solvent also undergoes change, so there must be successive additions of indigo and alkali; the principal attention of the dyer is the maintaining the proper relation of these matters, as too much or too little of either is injurious.

Sulphate of indigo forms an intense blue solution, unaffected also by mordants. Vegetable stuffs dipped in this retain no dye, for the washing off the acid in order to preserve the fibre removes the color; but animal fibre, such as woollen and silk, becomes dyed; a portion of the blue remains upon the stuff after washing off the acid, being retained by capillary attraction. This dye is termed Saxon blue, but it has very little of the permanence of indigo or vat blue, although it is also a substantive color.

Another truly substantive color is that dyed by carthamus or safflower, but the fixation of this dye upon the stuff differs from any of those referred to. Like indigo, it has no affinity for any base or substance capable of forming a mordant; its solvent is an alkali, but in this dissolved state it does not form a dye. The mode of proceeding in dyeing with carthamus is first to extract the dye from the vegetable in which it is found, by soda or potash, which is afterwards neutralized by an acid previous to dyeing, which renders the color insoluble, but in so fine a state of division that no precipitation can be seen for some time, and the stuff immersed in this imbues the color within its fibre, its lightness assisting this action, as the precipitate will remain suspended in water for days before it will subside. Vegetable fibre takes up this dye as easily as animal, but whether by an attraction for the stuff, or by a mechanical capillary attraction of the fibre, is not so easily determined. A piece of stuff suspended in a vessel filled with water, having in it some insoluble carthamine, all the coloring particles will flow to and combine with the fibre from a considerable distance, giving a proof of the existence of some force drawing them together.

Such then are the various conditions and principles involved in the processes of fixing the dye within or upon the stuff.

During the operations of dyeing there are certain circumstances which have to be attended to, in order to facilitate and effect certain lines or tints of color. Thus, with many of the coloring substances, heat not only favors but is necessary for the solution of the dye, and also its combination with the stuff or mordant. Decocations of woods are always made by hot water, and the dyeing processes with decoctions are in hot liquor. When the coloring matter of quercitron-bark is extracted by boiling water, the color produced upon the stuff will be a rich amber yellow, but if the extract be made by water at 180° Fahr., a beautiful lemon yellow will be the dye produced by it, using the same mordant in each case. Colors dyed by madder and Barwood must be done at a boiling heat during the whole process, or no dye is effected. Sumach, another astringent substance, is most advantageously applied at a boiling heat; and in order to have a large body of this dye fixed upon the stuff, it should be immersed in the liquor while hot and allowed to cool together, during which the tannin of the dye undergoes some remarkable change in contact with the stuff. Safflower dyes are kept cold, so are tin bases, Prussian blues, and chrome yellows: by applying heat to the last a similar result is effected to that with bark; instead of a lemon yellow an amber yel-
low will be obtained. Almost all colors are affected less or more by the temperature at which they are produced. Some mordants are fixed upon the stuff by heat, such as acetate of alumina; the stuff being dried from a solution of this salt at a high temperature loses part of the acid by being volatilized, and there remains upon the fibre an insoluble suboxide, which fixes the dye. These remarks respecting the methods apply more particularly to vegetable stuffs, as cotton, and in many cases also to silk, but wood is always dyed at a high heat. Although wool seems to have a much greater absorbing power than cotton, the latter will absorb and become strongly dyed in a cold dye bath, in which wool would not be affected; but apply heat and the wool will be deeply dyed, and the dye much more permanent than the cotton.

The permanence of colors is another property to be carefully studied by the practical dyer, as the color must not be brought under circumstances that will destroy its permanency during any of the operations of the dye-house. The word permanent, however, does not mean fast, which is a technical term applied to a color that will resist all ordinary operations of destruction. As, for instance, a Prussian blue is a permanent color, but not a fast color, as any alkaline matter will destroy it; or a common black is permanent, although any acid matters will destroy it; while Turkey red is a fast color, and not affected by either acid or alkaline matters. A few of the circumstances affecting colors in the processes they are subjected to may be referred to in this place. If, for instance, the air in drying the dyed stuff in a hot chamber be moist, there is a great tendency to the color being impaired in these circumstances. For example, a red color dyed with safflower will pass into brown, a Prussian blue will pass into a gray lavender, chrome yellows take an amber tint. Mostly all colors are affected less or more by being subjected to strong heat and moisture; even some of those colors termed fast are affected under such circumstances. A dry heat has little or no effect upon any color, and a few colors are made brighter in their tint by such a heat, as chrome orange, indigo blue, on cotton, &c.

Some of these effects of heat and moisture differ with different stuffs; thus indigo blue upon cotton is not so much affected as indigo blue upon silk, while safflower red upon cotton will be completely destroyed before the same color upon silk will be perceptibly affected. The same coloring matter fixed by different mordants upon the same stuff is also differently affected under these conditions.

Light is another agent effecting a great influence upon the permanence of colors, which should be also considered by the dyer. Red dyed by a Brazil wood and a tin mordant, exposed to the light, become brown; Prussian blue takes a purple tint; yellow becomes brownish; safflower red, yellowish, and these changes are facilitated by the presence of moisture; such as exposing them to strong light while drying from the dye-bath, either out or within doors. The direct rays of the sun destroy all dyed colors; even Turkey red yields before that agency.

Boiling was formerly prescribed in France as a test of fast dyes. It consisted in putting a sample of the dyed goods in boiling water, holding in solution a determinate quantity of alum, tartar, soap, vinegar, &c. Dufay improved that barbarous test. He considered that fast-dyed cloth could be recognized by resisting an exposure of twelve hours to the sunshine of summer, and to the midnight dews; or of sixteen days in winter.

In trying the stability of dyes, we may offer the following rules:

That every stuff should be exposed to the light and air; if it be intended to be worn abroad, it should be exposed also to the wind and rain; that carpets, moreover, should be subjected to friction and pulling, to prove their tenacity; and that clothes to be washed should be exposed to the action of hot water and soap. However, such tests are not at all applicable to most of the colors dyed upon cotton stuff. Not many of them can stand the action of hot water and soap, or even such acids as the juice of fruits. Indigo blue, one of the most permanent dyes on cotton, yields its intensity to every operation of washing, even in pure water.

1. Red with blue produces purple, violet, liliac, pigeon's neck, mallow, peach-blossom, bleu de roi, linit-blossom, amaranth.

Thus a Persian blue dyed over a safflower red, or vice versa, will produce any of these tints by varying the depth of the red and blue according to the shade required; but the same shades can be produced direct by logwood and an aluminois or tin mordant; the stuff being steeped in sumach liquor previous to applying the tin mordant produces the reddish or purple tint when such is required.

2. Red with black; brown, chocolate, maroon, &c. These tints are produced by various processes. To dye a deep orange by ammoto liquor, and then form over it a black by sumach and sulphate of iron, gives a brown; or dye the stuff first a rich yellow by quercitron and a tin mordant, and then over the yellow produce a purple by passing it through logwood; chocolates are thus produced. A little Brazil wood with the logwood gives more of the red element. When maroon is required, the red is made to prevail, and so by a judicious mixture these various tints are produced. Brown, especially upon cotton fibre, is more often produced direct by means of catechu. Steep the stuff in a hot solution ofcate
EDGE TOOLS.

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ch, in which the gummy principle has been destroyed by the addition of a salt of copper; then pass through a solution of bichromate of potash at boiling heat, when a rich brown is obtained.

3. Yellow with blue: green of a great variety of shades, such as naseent green, gay green, grass green, spring green, Laurel green, sea green, celadon green, parrot green, cabbage green, apple green, duck green. Green is essentially a mixed dye, and produced by dyeing a blue over a yellow or a yellow over a blue. In almost all cases the blue is dyed first, and then the yellow, and according to the depth of each or any of these are the various tints of green produced. With silk and wool, one kind of green dye may be produced simultaneously by putting sulphate of indigo into the yellow dye-bath, and then working the previously prepared or mordanted stuff in this. With cotton, an arsenite of copper (Scheele's green) may be produced by working the stuff in a solution of arsenite of potash or soda, and then in sulphate of copper, which produces a peculiar tint of green.

4. Mixtures of colors, three and three, and four and four, produce an indefinite diversity of tints: thus, red, yellow, and blue form brown olives and greenish grays; in which the blue dye ought always to be first given, lest the indigo vat should be soiled by other colors, or the other colors spoiled by the alkaline action of the vat. Red, yellow, and gray, (which is a graduation of black,) give the dead-leaf tint, as well as dark orange, snuff color, &c. Red, blue, and gray give a vast variety of shades; as leaf gray, slate gray, wood-pigeon gray, and other colors too numerous to specify. See Brown Dye.

Care must be taken, however, in mixing these colors, to study the depth of the tint required; as, for instance, were we wishing to dye a slate gray, and to proceed first by dyeing a blue, then a red, with a little of the gray, we would produce, instead of a slate gray, a purple or peach. The arrangement referred to, applies only to the elements of the colors that enter into the composition of the various tints, so that a slate gray is a blue with a small portion of red, and a still smaller portion of the black element, that produces the gray tint. Thus, dye the stuff first a deep sky-blue by the vat, then by passing through a solution of sumach, with a small quantity of logwood, Brazil wood, copperas, and alum, gray will be produced. The Brazil wood gives the red tint, sumach and copperas the black tint, the logwood assisting in this, and with the aid of the alum throwing in the paste or dove-neck hue; and thus, by the variation of these hues by such arrangements, any of the gray tints can be produced. See Calico Printing.

EBONY. Of this black wood three kinds are imported:—

The Mauritius Ebony, which is the blackest and finest grain.

The East Indian Ebony, which is not of so good a color.

The African Ebony, which is porous, and bad in point of color.

The ebony of the Mauritius is yielded by the Diospyros Ebenus. Colonel Lloyd says this ebony, when first cut, is beautifully sound, but that it splits like all other woods from neglectful exposure to the sun. The workmen who use it immerse it in water as soon as it is felled for from six to eighteen months; it is then taken out, and the two ends are secured from splitting by iron rings and wedges. Colonel Lloyd considers that next to the Mauritius, the ebony of Madagascar is the best, and next that of Ceylon. The Mauritius ebony is imported in round sticks like scaffold poles, about fourteen inches in diameter. The East Indian variety comes to us in logs as large as twenty-eight inches diameter, and also in planks. The Cape of Good Hope ebony arrives in England in billets, and is called billet wood, about from three to six feet long, and two to four inches thick.

The uses of ebony are well known.

White Ebony comes from the Isle of France, and is much like box-wood.

EDGE TOOLS; more properly cutting tools, of which the chisel may be regarded as the type. Holtzapfiel, whose book on Mechanical Manipulation is the best to be found in any language, divides cutting tools into three groups, —namely, paring tools, scraping tools, and shearing tools.

First. Paring or splitting tools, with thin edges, the angles of which do not exceed sixty degrees; one plane of the edge being nearly coincident with the plane of the work produced, (or with the tangent in circular work.) These tools remove the fibres principally in the direction of their length, or longitudinality, and they produce large coarse chips or shavings, by acting like the common wedge applied to mechanical power.

Secondly. Scraping tools, with thick edges, that measure from sixty to one hundred and twenty degrees. The planes of the edges form nearly equal angles with the surface produced, or else the one plane is nearly or quite perpendicular to the face of the work, (or becomes as a radius to the circle.) These tools remove the fibres in all directions with nearly equal facility, and they produce fine dust-like shavings by acting superficially.
ELASTIC BANDS.

Thirdly, Shearing, or separating tools, with edges of from sixty to ninety degrees; generally duplex, and then applied on opposite sides of the substances. One plane of each tool, or of the single tool, coincident with the plane produced.

ELASTICITY. *Elastica elatina, Fr.; Foderhaz-zeige, Germ.*) See CAOUTCHOUC and BRANDING MACHINE.

ELASTICITY. The property which bodies possess of occupying, and tending to occupy, portions of space of determinate volume, or determinate volume and figure, at given pressures and temperatures, and which, in a homogeneous body, manifests itself equally in every part of appreciable magnitude, (Nichol.) The examination of this important subject in KINETICS does not belong to this work. A few remarks, and some explanations, only are necessary.

Elastic Pressure is the force exerted between two bodies at their surface of contact.

Compression is measured by the diminution of volume which the compressible (elastic) body undergoes.

The Modulus or Coefficient of Elasticity of a liquid is the ratio of a pressure applied to, and exerted by, the liquid to the accompanying compression, and is therefore the reciprocal of the compressibility. The quantity to which the term Modulus of Elasticity was first applied by Dr. Young, is the reciprocal of the extensibility or longitudinal pliability. (See the Edinburgh Transactions, and those of the Royal Society, for the papers of Barlow, Maxwell, and Rankine, and the British Association Reports for those of Fairbairn, Hodgkinson, &c.)

Various tables, showing the elasticity of metals, glass, &c., have been constructed, and will be found in treatises on mechanics. The following notices of the mechanical properties of woods may prove of considerable interest. The experiments were by Chevandier and Wertheim.

Rods of square section 10 mm in thickness and 2 m in length were prepared, being cut in the direction of the fibres, and the velocity of sound in them was determined by the longitudinal vibrations, their elasticity from their increase in length, and their cohesion by loading them to the point of rupture. Small rods were cut in planes perpendicular to the fibre grain, (in directions radial and tangential to the rings of growth,) and their elasticity and sound velocity were measured by the lateral vibrations. It was thus again established, that the coefficients of elasticity, as deduced from the vibrations, come out higher than those derived from the elongation.

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<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Acacia</td>
<td>0.712</td>
<td>14.9</td>
<td>E.</td>
<td>L.</td>
</tr>
<tr>
<td>Fir</td>
<td>0.493</td>
<td>13.96</td>
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<tr>
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<tr>
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<tr>
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<td>7.76</td>
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<tr>
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<tr>
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<tr>
<td>Elm</td>
<td>0.906</td>
<td>8.56</td>
<td>7.61</td>
<td>12.36</td>
</tr>
</tbody>
</table>

L refers to rods cut lengthwise with the grain, E to those cut in a direction radial, and T to those tangential to the annual rings.

ELDER. *Sambucus nigra, Sureau, Fr.; Hohhinder, Germa.*) Pith balls for electrical purposes are manufactured from the pith of the elder tree, dried. The wood is employed for inferior turnery work, for weavers' shuttles, netting pins, and shoemakers' pegs. Its elasticity and strength render it peculiarly fitted for these latter purposes.

ELECTRIC CLOCKS. The application of electricity as a motive power to clocks, and as a means of transmitting synchronous signals or time, is naturally intimately connected with the attempts (not yet realized in an economic point) to apply it as a motive power to machinery, and with its application, so fully realized, (see article Electro-Telegraphy,) to telegraphy proper; and it has grown up side by side with the latter. Prof. Wheatstone's experiments, as recorded to it in the very early days of telegraphs. Without entering upon the history of electric clocks, it will suffice to describe two principles on which they have been constructed, and which are best known,—Bain's and Shepherd's. In the former, electricity maintains the pendulum in motion, and the pendulum drives the clock-train; in the latter, the motion of the pendulum is maintained by electricity, but the clock-train is driven by distinct currents, sent to it by means of pendulum contacts.
The bob of Bain's pendulum consists of a coil of wire, wound on a bobbin with a hollow center. The axis of the bobbin is horizontal. Bar magnets, presenting similar poles, are fixed on each side of the coil, in such a position that, as the pendulum oscillates right and left, the poles on either side may enter the coil of wire. It is one of the laws of electric currents, when circulating in a helix, or spiral, or coil, or even in a single ring, that each face of the coil presents the characters of a magnetic pole; of a south pole if the current circulates in the direction in which the hands of a watch move; of a north pole, if it circulates in the reverse direction. Things are so arranged in Bain's pendulum, that a battery current is alternately circulating in and cut off from the coil. When the current is circulating, the coil has the character of a magnet, with a north end and a south end; if the permanent magnets present north poles, the north end of the coil-bob will be repelled from one of the magnets, while its south end will be attracted by the other magnet. This constitutes the impulse or maintaining power in one direction. Now the connections are such that, when the arc of vibration is complete and the pendulum ready for the return vibration, the pendulum rod pushes aside a golden slide, by which the electric circuit had been completed, and the current is cut off; the pendulum is thus able to make its return vibration by mere gravity. It starts to repeat the above operations by mere gravity; but, ere it completes the arc, the rod pushes back the slide, and again completes the electric circuit, and gives rise to a second impulse, and so on. A small amount of magnetic attraction is sufficient to supply the necessary amount of maintaining power. One pair of zinc-copper, buried in the moist earth, has been found ample.

In an ordinary clock, the train is carried by a weight or by a spring, and the time is regulated by the pendulum. In Bain's the time is regulated and the train is driven by the pendulum. The rod hangs within a crutch in the usual way; the crutch carries pallets of a particular kind, acting in a scape-wheel; and from the latter, the motion is transmitted to a train of the usual character, but much lighter. For large clocks, Mr. Bain proposes a modification of the slide, which shall invert the current at each oscillation, so as to have attraction as a maintaining power in both oscillations. The general arrangement of the pendulum is shown in fig. 250. \( \text{n} \) is the pendulum bob, with its coil of wire, the ends of which pass up on either side of the rod. \( \text{x} \) and \( \text{c} \) are the battery plates, with their attached wires \( \text{a} \) and \( \text{a}' \). The arrows show the course of the volute current from the plate \( \text{c} \) by the wire \( \text{n}' \), thence down the pendulum rod by the right hand wire, through the coil \( \text{n} \), up by the wire on left side of rod, then by the wire \( \text{c} \), along the slide at \( \text{x} \), and by the wire \( \text{n} \) to the zinc plate \( \text{z} \). When the slide \( \text{x} \) is in position, the circuit is complete, and the bob is attracted by the \( \text{n} \) pole of one of the magnets, and repelled by the \( \text{n} \) pole of the other. When the slide is displaced, the attraction ceases, and the pendulum is left to the mere action of gravity.

Shepherd's electric clock has a remontor escapement. There is no direct connection between the electric force and the pendulum, or between the pendulum and the clock-train. The attractive power, derived from the electric current, is simply employed to raise the same small weight to the same height; and the clock-train is carried by the attractive force derived from electric springs whose circuits are completed by the pendulum touching contact springs. The pendulum is thus protected from the influence of change in the force of the current, or from irregular resistances in the train. Fig. 251 is a perspective view of this pendulum, with batteries \( \text{s} \) \( \text{z} \) attached, and the clock connections and those of its batteries \( \text{s} \) \( \text{z} \) shown. The electricity leaves the pendulum battery by the wire \( \text{a} \), and returns to it by the wire \( \text{r} \). There is only one break in this circuit, namely, at \( \text{x} \), which is a slender spring fixed with platinum, that is in contact with platinum on the pendulum at the extreme of its
right vibration, but at no other time. The wire a reaches the pendulum from the battery by the coils b, the plate c, and the frame d; the wire e goes direct from the spring e to the zinc z. From this arrangement, it happens that every time the contact at e is completed, the iron core, of which the ends n s are visible, contained within the coils b, becomes a magnet, and when the contact at e is broken, the magnetism ceases. The poles n s have, therefore, a power alternately to attract and to release a, which is a plate or armature of soft iron, moving on an axis, as shown in the figure, and to which is attached a bar b, with a counterpoise i. We have said that the office here of the electric force, is merely to raise a weight; the fall of the weight maintains the pendulum in motion. When the armature a is attracted, the lever b is raised; this raises the wire c into a horizontal position, and its other part d into a vertical position; the latter is caught and retained by the latch or detent.
Electric Clocks.

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e; so that when the magnetic attraction ceases, the counterpoise \( i \) descends with the lever \( b \); and so the armature \( a \) leaves the electro-magnet \( x\)s. But the wire \( d \) remains vertical, and its other part with the small weight \( e \) remains horizontal. Now, when the pendulum makes its left hand oscillation, the point of the screw \( f \) impinges upon the stem \( g \), and carries it a little to the left; this raises the detent \( e \), and liberates the piece \( d \), which descends into its original position by gravity; the small ball \( c \) adds to its weight. In descending, the vertical piece \( c \) strikes against the point of the screw \( k \), and gives a small impulse to the pendulum \( p \). The ball \( e \) is not larger than a pea, and its fall is not an eighth of an inch; but the impulse is sufficient to keep the pendulum in motion; and it is constant, being this same body falling through the same space; and is independent of any variation in the battery power, which latter is only concerned in raising the ball. The arc of the pendulum's vibration is regulated by adjusting the small ball to a greater or less distance from the centre. Provision is thus made for maintaining the pendulum in motion, and giving it an impact of constant value. If this arrangement is in connection with a compensating mercurial pendulum, extreme accuracy of time-keeping is attained. The next step is to transfer the seconds, thus secured, to a dial or clock. The same movement of the keeper \( a \) with its counterpoise \( i \), has sometimes been made to impart motion to the seconds wheel of a clock-train; but more commonly the clock-train is distinct, as shown in the drawing, and is carried by a special electro-magnetic arrangement, in connection with separate batteries, \( e, e, e \), the contacts of which are, however, under the control of the pendulum. Insulated springs, \( k \) and \( l \), are fixed near the top of the rod; from \( k \) a wire leads to the silver \( s \), of the left hand battery; and from \( l \) another wire leads to the zinc \( z \), of the right hand battery. The other metals of the respective batteries are connected by a wire with an electro-magnet within the clock, the other end of the said electro-magnet being connected with the metal bed and frame of the pendulum. When, therefore, the pendulum oscillates to the right, the circuit is completed at \( f \); and the current of the left hand battery circulates from \( s \) through the wire \( k \) and through the metal frame, and by the wire to the clock, and so to the zinc \( z \). When the oscillation is to the left and \( f \) is in contact, the right hand battery is in action; and the current circulates from \( s \) through the clock, to the metal frame, and thence to \( l \) and to the zinc \( z \) of the battery. In one case, a voltaic current enters the clock by the wire shown below, and leaves it by the upper wire; and, in the other case, it enters by the upper wire and leaves by the lower. There is a double set of electro-magnets within the clock, showing four poles in all; there are also two magnetised steel bars, mounted see-saw fashion, with their poles alternate, and facing the four electro-magnetic poles. When the current enters the clock from below or in one direction, the bars oscillate this way; when it enters from above or in the reverse direction, they oscillate that way. They are both fixed at right angles to and upon the same axis; which axis carries a pair of driving pallets, that act on a sprocket-wheel, and so the clock-train is driven. It will be seen at a glance, that one, or more clocks may be connected in the same circuit, as readily as one; it being merely necessary in such case to modify the battery power, to correspond with the work to be done. For instance, three such clocks have been going for several years at Toulbridge by the same pendulum; several are actuated in like manner at the Royal Observatory, Greenwich. Nor is it necessary that the clocks should be in the same room with the pendulum, or in the same building, or even in the same parish. All the clocks are above referred to, are variously distributed; and one of the Observatory clocks is six miles distant from its pendulum, being at the London Bridge Station of the South-Eastern Railway.

In cases where it has not been found convenient to drive the clock-train, especially in the case of a public one, the movement of which is heavy, great advantage has been derived for regulating the oscillations of the pendulum of the large clock, by means of electro currents, under the control of a standard pendulum. Mr. Jones has adopted this method, and it is likely to meet with much favor. The turret-clock, under this arrangement, is driven by weights in the usual way, and the time is regulated by a pendulum. The bob of the pendulum is placed under a condition analogous to that of Bain's, (fig. 250,) the permanent magnet, however, being attached to the pendulum, and the electro-magnet fixed being it. If currents are made to circulate synchronously in the latter, by means of a standard pendulum, the oscillations of the pendulum of the turret-clock are constrained to accord with those of the standard, and a very perfect system of time-keeping is obtained. This is practised at Liverpool, and has just been introduced at Greenwich.

Under the above arrangements the clock is controlled by the standard pendulum second by second, and the two keep time together throughout the day. There are cases in which it is sufficient, and also more convenient, to correct a clock once a day only by means of a telegraph signal from a standard clock. This is managed in several ways. There is a clock at the Telegraph Office in the Strand; a good regulator, adjusted to gain a second or two during the twenty-four hours, and to stop at 1 p.m. A telegraph signal is sent from the Royal Observatory precisely at 1, that drops a time-ball at the Strand office, which, in falling, starts the clock. At Ashford, seventy-three miles from Greenwich, there is an electric clock which has a gaining rate, and which is so constructed that the battery
circuit is opened at 1 o'clock by means of pins and springs attached to the movement, and the clock therefore stops. At 1 p.m., Greenwich mean time, a signal is sent through the Ashford clock from the Royal Observatory, which starts it at once at true time. At the Post Office, Lombard Street, there is a clock which, in the course of the twenty-four hours, raises a weight. At noon a telegraph signal is sent from Greenwich, which passes through an electro-magnet; the latter attracts an armature of soft iron and liberates the ball, which falls, and in falling it encounters a crutch, or lever, attached to the seconds' hand, and thrusts it this way or that, as the case may be; but so as to bring it to sixty seconds on the dial, and thus to set the clock right.

Intermediate between the one method of sending a signal every second to regulate a clock, and the other method of sending it once a day, we have the following arrangement of Bain's for sending it once an hour. Fig. 252 shows the arrangement, with part of the dial removed, to show the position of the electro-magnet. The armature is below; it carries a vertical stem, terminating above in a fork. Its ordinary position is shown by the dotted lines. The minute hand (partly removed from the dial) carries a pin on its back surface. When the hand is near to sixty minutes, and an electric current is sent through the magnet, the armature is attracted upwards and the fork takes the position shown by the full lines at the top of the dial, and, in doing so, it encounters the pin and forces the hand into the correct position, and sets the clock to true time, providing the signal comes from a standard clock, or is sent by hand at true time. A dial of moderate character keeps so near to time, that once or twice a day would be, for all common purposes, often enough to correct it.

Fig. 253 is an arrangement of Bain's, by which a principal clock, showing seconds, sends electric currents at minute intervals to other clocks, and causes the hand to move minute by minute. A is a voltaic battery; 2 is the principal clock, which may be an electric clock or not, at pleasure; f and g are two out of many subordinate clocks. The seconds' hand of the principal clock completes a voltaic circle twice (for the case of two clocks) during the minute; at the 50 seconds for the clock f, and at the 60 seconds for the clock g. The clock f shows time in leaps from one minute to the next; and the clock g from one half minute to the next half minute. As many more contacts per minute may be provided for the seconds' hand of the prime clock as there are subordinate clocks.

Next akin to the time signals above described, and which act automatically upon clocks, either to drive the clock-train or to correct the clock errors, are mere time signals, which are extensively distributed throughout the country by the ordinary telegraph wires, and are looked for at the various telegraph stations, in order to compare the office dials with Greenwich mean time, and to make the necessary correction; they are also redistributed by hand the moment they appear, through sub-districts branching from junction stations. Large
black balls, hoisted in conspicuous stations, are also dropped daily by electric currents in various places, for the general information of the public, or of the captains of ships.—C. V. W.

**ELECTRICITY for Blasting in Mines and Quarries.** Professor Hare was the first who entertained this idea, but Mr. Martin Roberts devised the following process:—In order not to be called upon to make afresh a new apparatus for each explosion, Mr. Roberts invented cartridges, which may be constructed beforehand. With this view, two copper wires are procured, about a tenth of an inch in diameter, and three yards in length, well covered with silk or cotton tarred, so that their insulation may be very good. They are twisted together (fig. 254) for a length of six inches, care being taken to leave their lower extremities free, for a length of about half an inch, (separating them about half an inch,) from which the insulating envelope is removed, in order to stretch between them a fine iron wire, after having taken the precaution of cleaning them well. The upper extremities of the two copper wires are likewise separated, in order to allow of their being placed respectively in communication with the conductors, that abut upon the poles of a pile. The body of the cartridges is in a tin tube, three inches long and three-quarters of an inch in diameter, the solderings of which are very well made, in order that it may be perfectly impermeable to water. A glass tube might equally well be employed, were it not for its fragility, which has caused a tin tube to be preferred. The system of copper wires is introduced into the tube, fixing them by means of a stem that traverses it at such a height that the fine iron wire is situated in the middle of the tin tube, so arranged that the ends of the copper wire do not anywhere touch the sides of the tube, (fig. 255.) The cork is firmly fixed at the upper extremity of the tube with a good cement. Mr. Roberts recommends for this operation, a cement composed of one part of beeswax and two parts of resin; the tube is then filled with powder by its other extremity, which is likewise stopped with a cork, which is cemented in the same manner. Fig. 256 indicates the manner in which the cartridge is placed in the hole, after having carefully expelled all dust and moisture: care must be taken that the cartridge is situated in the middle of the charge of powder that is introduced into the hole. Above the powder is placed a plug of straw or tow, so as to allow between it and the powder a small space filled with air; and above the plug is poured dry sand, until the hole is filled with it. The two ends of the copper wires that come out of the cartridge are made to communicate with the poles of the pile, by means of conductors of sufficient length, that one may be protected from all dangers arising from the explosion of the mine.

M. Ruhmkorff, and after him, M. Verdu, have successfully tried to substitute the induction spark for the incandescence of a wire, in order to bring about the ignition of the powder. This process, besides the considerable economy that it presents—since, instead of from fifteen to twenty Bessecon's pairs, necessary for causing the ignition of the wire, it requires but a single one for producing the induction spark—possesses the advantages of being less
susceptible of derangement. Only it was necessary to contrive a plan to bring about the ignition of the powder; in fact, it happens, that when by the effect of the length of the conductors that abut upon the mine, the circuit presents too great a resistance, the induction spark is able to pass through the powder without inflaming it. M. Ruhmkorff has conceived the happy idea of seeking for a medium, which, more easily inflammable by the spark, may bring about the ignition of the powder in all possible conditions. He found it in Statham's fuses, which are prepared by taking two copper wires covered with ordinary gutta percha; they are twisted, (fig. 257,) and the ends are bent so as to make them enter into an envelope of vulcanized (sulphured) gutta percha, which has been cut and drawn off from a copper wire that had been for a long time covered with it. Upon this envelope a sloping cut, a, b, is formed; and after having maintained the extremities of the copper wires at about the eighth of an inch from each other, their points are covered with fulminate of mercury, in order to render the ignition of the powder more easy. The cut is filled with powder, and the whole is wrapped round with a piece of caschbone tube, c, d, or else it is placed in a cartridge filled with powder.

In the Statham fuses, it is the sulphide (sulphuret) of copper adhering to the wire, produced by the action of the vulcanized gutta percha which is removed from the copper wire that it covered, which, by being inflamed under the action of the induction spark, brings about an explosion. But it is necessary to take care when the fusee has been prepared, as we have pointed out, to try it in order to regulate the extent of the solution of continuity. It might, in fact, happen that while still belonging to the same envelope of a copper wire, the sheath of a vulcanized gutta percha with which the fusee is furnished, may be more or less impregnated with sulphide of copper; now, if the sulphide of copper is in too great quantity, it becomes too good a conductor, and prevents the spark being produced; if, on the contrary, it is not in a sufficiently large quantity, it does not sufficiently facilitate the discharge.

The first trials on a large scale of the application of the process that we just described, were made with Ruhmkorff's induction apparatus, by the Spanish colonel, Verdu, in the workshops of M. Herkman, manufacturer of gutta percha covered wire, at La Villette, near Paris. Experiments were made successively upon lengths of wire of 400, 600, 1,000, 5,000, and up to 26,000 metres, (of 3'28 feet,) and the success was always complete, whether with a circuit composed of two wires, or replacing one of the wires by the earth; two ordinary Bunsen's pairs were sufficient for producing the induction spark with Ruhmkorff's apparatus. Since his first researches with M. Ruhmkorff, M. Verdu has applied himself to fresh researches in Spain; and he was satisfied, by many trials, that of all explosive substances, not one was nearly so sensitive as fulminate of mercury; only, in order to avoid the danger that arises from the facility of explosion of this compound, he takes the precaution of introducing the extremity of the fusees into a small gutta percha tube, closed at the end. After having filled with powder this species of little box, and having closed it hermetically, the fusees may be carried about, may be handled, may be allowed to fall, and even squeezed rather hard, without danger. The elastic and leather-like nature of gutta percha, which has been carefully softened a little at the fire, preserves the fulminate from all chance of accident. We may add, that with a simple Bunsen's pair, and by means of Ruhmkorff's induction apparatus, M. Verdu has succeeded in producing the simultaneous explosion of six small mines, interposed in the same circuit at 320 yards from the apparatus. He has not been beyond this limit; but he has sought for the means of acting indirectly upon a great number of mines, by distributing them into groups of five, and by interposing each of these groups in a special circuit. The fusees of each group are made to communicate by a single wire, one of the extremities of which is buried in the ground, and whose other extremity is near to the apparatus. On touching the induction apparatus successively with each of the free ends that are held in the hand, which requires scarcely a second of time, if there are four wires, that is to say, four groups and consequently twenty mines, twenty explosions are obtained simultaneously at considerable distances. There are no limits either to the distance at which the explosion may take place, or to the number of mines that may thus be made to explode.

ELECTRIC LIGHT. Various attempts have been made, from time to time, to employ electricity as an illuminating power; but hitherto without the desired success. The voltaic battery has been employed as the source of electricity, and in nearly all the arrangements, the beautiful arc of light produced between the poles, from the points of the hardest charcoal, has been the illuminating source. One of the great difficulties in applying this agent arises from the circumstance that there is a transference of the charcoal from one pole to the other, and consequently an alteration in the distance between them. This gives rise to considerable variations in the intensity and color of the light, and great want of steadiness. Various arrangements, many of them exceedingly ingenious, have been devised to overcome these difficulties.

The most simple of the apparatus which has been devised is that of Mr. Staite, which has been modified by M. Archereau. Two metal columns or stems, to which any desired
form can be given, are connected together by three cross pieces, so as to form one solid frame; one of these cross pieces is metallic; it is the one which occupies the upper part of the apparatus; the others must be of wood. These latter serve as supports and points of attachment to a long bobbin placed parallel to the two columns and between them, and which must be made of tolerably thick wire, in order that the current, in traversing it without melting it, may act upon a soft iron rod placed in the interior of the bobbin. This iron rod is soldered to a brass stem of the same calibre, and of the same length, carrying at its free extremity a small pulley. On the opposite side the iron carries a small brass tube, with binding screws, into which is introduced one of the carbons, when the entire rod has been placed in the interior of the bobbin. Then a cord fixed to the lower cross piece, and rolling over a pulley of large diameter, is able to serve as a support to the movable iron rod, running in the groove of the little pulley. For this purpose, it only requires that a counterpoise placed at the end of the cord shall be enabled to be in equilibrium with it. The metal cross piece which occupies the upper part of the apparatus, carries a small brass tube, whose descends perpendicularly in front of the carbon that is carried by the electro-magnetic stem, and into which is also introduced a carbon crayon. By means of a very simple adjustment, this tube may besides be easily regulated, both for its height and for its direction; and consequently the two carbons may be placed very exactly above one another. The apparatus being adjusted, we place one of the two metal columns of the apparatus in connection with one of the poles of the pile, and cause the other pole to act upon the copper wire of the bobbin, (one end of which is soldered upon its socket.) The current then passes from the bobbin to the lower carbon by the rod itself that supports it, and passing over the interval separating the two carbons, it arrives at the other pole of the pile by the upper cross piece of the apparatus and the metal column, to which one of the conducting wires is attached. So long as the current is passing and producing light, the bobbin reacts upon the iron of the electro-magnet rod, which carries the lower carbon and attracts it on account of the magnetic reaction that solenoids exercise over a movable iron in their interior. It is this which gives to the carbons a separation sufficient for the luminous effect. But immediately the current ceases to pass, or is weakened, in consequence of the consumption of the carbons, this attraction ceases, and the movable carbon, acted on by the binding screws, is forced to be drawn down and raised until the current passes again; equilibrium is again established between the two forces, and the carbons may be employed again. Thus, in proportion as the light tends to decrease, the counterpoise reacts; and this is it that always maintains the intensity of the light equal.

M. Breton has an apparatus which differs somewhat from the above, and M. Foucault has also devised a very ingenious modification. But by far the most successful arrangement, for a description of which we are indebted to De la Rie's Treatise on Electricity, translated by C. V. Walker.

The two carbons, between which the light is developed, burn in contact with the air, and shorten at each instant; a mechanism is consequently necessary, which brings them near to each other, proportionally to the progress of the combustion; and since the positive carbon suffers a more rapid combustion than the negative, it must travel more rapidly in face of this latter; and this in a relation which varies with the thickness and the nature of the carbon. The mechanism must satisfy all these exigencies. The two carbons are uneasingly solicited towards each other, the lower carbon by a spiral spring, that causes it to rise, and the upper carbon by its weight, which causes it to descend. The same axis is common to them. The galvanic current is produced by a Bunsen's pile of from 40 to 50 elements: it arrives at the two carbons, as in apparatus already known, passing through a hollow electromagnet, concealed in the column of the instrument. When the two carbons are in contact, the circuit is closed, the electro-magnet attracts a soft iron, placed at the extremity of a lever, which is in gear with an endless screw. An antagonist spring tends always to unwind the screw as soon as a separation is produced between the two carbons; if it is a little considerable, the current no longer passes, the action of the spring becomes predominant, the screw is unwound, and the carbons approach each other until, the current again commencing to pass between the two carbons, the motion that drew them towards each other is relaxed in proportion to the return of the predominance of the electricity over the spring; the combustion of the carbons again increases their distance, and with it the superior action of the spring; hence follows again the predominance of the spring, and so on. These are alternatives of action and reaction, in which at one time the spring, at another time the electricity, has the predominance. On an axis, common to the two carbons, are two pulleys: one, the diameter of which may be varied at pleasure, communicates by a cord with the rod that carries the lower carbon, which corresponds with the positive pole of the pile; the other, of invariable diameter, is in connection with the upper or negative carbon. The diameter of the pulley, capable of varying proportionally to the system of the carbon, with which it is in communication, may be increased from three to five. The object of this arrangement is to preserve the luminous point at a convenient level, whatever may be the
thickness or the nature of the carbons. It is only necessary to know that, at each change of kind or volume of the carbon, the diameter of the pulley must be made to vary. This variation results from that of a movable drum, communicating with six levers, articulated near the centre of the sphere; the movable extremity of the six arms of the lever carries a small pin, which slides in cylindrical slits. These slits are oblique in respect of the sphere; they form inclined planes. A spiral spring always rests upon the extremity of the levers; so that, if the inclined planes are turned towards the right, the six levers bend towards the centre, and diminish the diameter. If, on the contrary, they are turned towards the left, the diameter increases, and with it the velocity of the translation of the carbon, which communicates with the pulley. We may notice, in passing, that this apparatus is marvellously adapted to the production of all the experiments of optics, even the most delicate; and that, in this respect, it advantageously supplies the place of solar light. As it is quite impossible to describe accurately the minute arrangements of this instrument, the letters of reference have not been used in the text.
ELECTRO-METALLURGY.

Dr. Richardson informs us, that although Mr. Grove calculated, some years ago, that for acid, zinc, wear and tear, &c., of batteries, a light equal to 1,444 candle power could be obtained for about 3a. 6d. per hour, the cost of the light employed for about five minutes at Her Majesty's Theatre, as an incident in the ballet, which was obtained by employing 75 cells of Callan's battery of the largest size, was said to be £2 per night, or at the rate of £20 per hour. In this calculation we expect we have not a fair representation of all the conditions. To obtain a light for ten minutes, a battery as large must be used as if it were required to be maintained in activity for hours—and probably the battery was charged anew every evening. There can be no doubt but the cost of light or of any other force from electricity, with our present means of producing it, must be greatly in excess of any of our ordinary means of producing illumination. For a consideration of this subject, see Electro-Motive Engines. Mr. Grove proposed a light which should be obtained from incandescent platinum, but the objection to this was, that after a short period the platinum broke up into small particles, the electric current entirely disintegrating the metal. Mr. Way has lately exhibited a very continuous electric light, produced from a constant flow of mercury rendered incandescent by the passage of the electric current.

ELECTRIC WEAVING. M. Bonelli devised a very beautiful arrangement, by which all the work of the Jacquard loom is executed by an electro-magnetic arrangement. The details of the apparatus would occupy much space in the most concise description, and as the invention has not passed into use, although M. Froment has modified and improved the machine, we must refer those interested in the subject to the full description given in De la Rive's Traite on Electricity by Walker.

ELECTRO-METALLURGY. The art of working in metals was carried on exclusively by the aid of fire until the year 1839. At that epoch a new light dawned upon the subject; considerable interest was excited in the scientific world, and much astonishment among the general public, by the announcement that electricity, under proper management, and by most easy processes, could supersede the furnace in not a few operations upon metals; and that many operations with metals, which could scarcely be entertained under the old condition of things, might be placed in the hands of a child, when electricity is employed as the agent.

Public attention was first directed to the important discovery by a notice that appeared in the Athenæum of May 4, 1839, that Professor Jacob, of St. Petersburg, had "found a method of converting any line, however fine, engraved on copper, into a relief, by galvanic pressure." Jacob's own account of the matter was that, while at Dorpat, in February, 1837, prosecuting his galvanic investigations, a striking phenomenon presented itself, which furnished him with perfectly novel views. Official duties prevented his completing the investigation, thus opened out to him, during the same year; and it was not until October 5, 1838, that he communicated his discovery, accompanied with specimens, to the Academy of Sciences at St. Petersburg; an abstrat from which paper was published in the German Neue Annalen of the same place on October 30 of the same year. And in a letter of Mr. Lettsom, dated February 5, 1839, the nature of the discovery is thus given in the following March number of the Annals of Electricity. Speaking of a recent discovery of Professor Jacob's, he says, "He observed that the copper deposited by galvanic action on his plates of copper, could by certain precautions be removed from those plates in perfect sheets, which presented in relief most accurately every accidental indentation on the original plate. Following up this remark, he employed an engraved copper-plate for his battery, caused the deposit to be formed on it, and removed it by some means or other; he found that the engraving was printed thereon in relief, (like a wood-cut,) and sharp enough to print from." This paragraph does not appear to have caught the eye of the public so readily as the brief note that appeared a couple of months later in the Athenæum.

On May 8, or four days after the appearance of the notice in the Athenæum, Mr. Thomas Spencer gave notice to the Polytechnic Society of Liverpool that he had a communication to make to the Society relative to the application of electricity to the arts. He subsequently desired to communicate the result of his discoveries to the British Association, whose meeting was at hand; but, for some cause, which does not appear, the communication was not made; and it eventually was made public, as at first proposed, through the Polytechnic Society of Liverpool, on September 12, 1839. In the mean time, namely on May 22, Mr. J. Jordan, referring to the notice the Athenæum, wrote to the Mechanick Magazine that, at the commencement of the summer of 1838, he had made "some experiments with the view of obtaining impressions from engraved copper-plates by the aid of galvanism." His letter describing this process appears in the number for June 8. It occurred to him, from what he had gathered from previous experience, that an impression might be obtained from an engraved surface; and it was "for detaching the precipitated metal, and the most delicate and superficial markings, from the fine particles of powder used in polishing to the deeper touches of a needle or graver, exhibited their correspondent impressions in relief with great fidelity.

Mr. Spencer, in his communication, besides noticing the fidelity with which the traces
on an original plate were copied, recorded the case of a copper-plate that had become covered with precipitated copper, excepting in two or three places, where by accident some drops of varnish had fallen; whence it occurred to him, and experiment confirmed his conjecture, that a plate of copper might be varnished, and a design made through the varnish with a point, and copper might be deposited upon the metal at the exposed part, and thus a raised design be procured.

In the Philosophical Magazine for December, 1836, Mr. De la Rue, after describing a form of voltaic battery, refers to the well-known condition on which the properties of the battery in question mainly depend, that "the copper-plate is also covered with a coating of metallic copper, which is continually being deposited;" and he goes on to describe that "so perfect is the sheet of copper thus formed, that being stripped out, it has the counterpart of every scratch of the plate on which it is deposited." Daniell himself, whose battery is here in question, noticed, as he could not fail to do in common with all who had employed his battery to any extent, the same peculiarities; but it does not appear that either he or De la Rue, or any one else, to whom the phenomenon presented itself before Jacobi, Jordan, or Spencer, caught the idea of its applicability in the arts. It would also appear that the impression came with the greater vividness to the two latter; for, while but little time seems to have been lost to them in realizing their idea, twenty long months elapsed between the time when the "perfectly novel views" first presented themselves to Professor Jacobi, and the time when his "well-developed galvanic production" was communicated to the Imperial Academy of Science. But, on the other hand, neither Mr. Jordan nor Mr. Spencer appears, as far as we are aware, to have been so sensible of the importance of the results to which they had arrived, as to have taken any steps to secure them as an invention or to publish them, until their attention was aroused by the previous publication of the successes of Jacobi.

Jacobi's "Galvano-Plastik," Smee's and also Shaw's "Electro-Metallurgy," Walker's "Electrotype Manipulation," four well-known works, on the subject, which present the different names under which the art is known; and from which it is gathered that metals may become, as it were, plastic under the agency of galvanic electricity, and may be worked and moulded into form. Voltaic pairs are described in general terms in the article on Electro-Telegraphy. The particular voltaic pair which led to the discoveries now before us, here requires special notice; because, on the one hand, while in use for other purposes, it was the instrument which first directed attention forcibly to the behavior of metals under certain conditions of electric current; and, on the other hand, it has been itself extensively used in electrotype operations. Professor Daniell first described his mode of arranging a voltaic pair in the Philosophical Transactions for 1836. Fig. 259 shows one cell complete of Daniell's combination, which from its behavior is called a constant battery. 2 is a copper vessel; b a rod of zinc, contained in a tube c of porous earthenware. The liquid within the tube c is salt and water, in which case the zinc is in its natural state; or, sulphuric acid and water, in which case the zinc is amalgamated; the latter arrangement being the more active of the two. The liquid in the outer vessel a consists of crystals of sulphate of copper, dissolved in water. At e is a perforated shelf of copper below the surface of the liquid, upon which are placed spare crystals of sulphate of copper, which dissolve as required, and serve to keep up the strength of the solution in proportion as the copper already there is extracted by the voltaic action hereafter to be described. a and b are screws, to which wires may be attached, in order to connect up the cell and convey the current from it into any desired apparatus. Certain chemical changes take place when this instrument is in action; oxygen from the water within the porous tube combines with zinc, making oxide of zinc, which enters into combination with sulphuric acid, producing as a final result sulphate of zinc; hydrogen is liberated from water in the outer cell, and itself liberates oxygen from oxide of copper, and combines with it, producing water, and leaving copper free. As far as the metals are concerned, zinc is consumed from the rod b, at the one hand, and copper is liberated upon the plate a, at the other end. These actions are slow and continuous; and the copper, as it is liberated atom by atom, appears upon the inner surface of the cell; and after a sufficient quantity has been accumulated, may be peeled off or removed; when it will be found to present the marks and features of the surface from which it has been taken, and which, as we have already said, arrested the attention of many into whose hands this instrument fell. A slight modification of the above arrangement gives us a regular electrotype apparatus. The cell c in this arrangement (fig. 260) is of glass or porce-
In fig. 259: and \( n \) a trough filled with an acid solution of sulphate of copper; \( w \) is a metal rod, on which the moulds are hung; and \( e \) a metal rod, upon which plates of copper are hung facing the moulds; the copper-plates are connected by the wire \( z \) with the copper of the battery cell, and the moulds by the wire \( x \) with the zinc rod. The voltaic current is generated in the cell \( a \), and its direction is from the zinc rod, through the solutions to the copper of the cell; thence by the wire \( z \) to the plates of copper \( e \); through the sulphate solution to the moulds \( m \); and thence by the wire \( x \) to the zinc rod. In this arrangement, no shelf is necessary in the trough \( n \) for crystals of sulphate of copper to keep up the strength of the solution; for the nature of the electro-chemical decompositions is such, that in proportion as copper is abstracted and deposited upon the moulds \( m \), other copper is dissolved into the solution from the plates \( c \). Water is the prime subject of decomposition. It is a compound body, consisting of the gases oxygen and hydrogen, and may be represented by fig. 262, where the arrows show the direction in which the current, by the wire \( p \), enters the trough \( n \) of fig. 261 by the plate of copper \( c \), and passes through the...
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Water in the direction shown, and leaves it after traversing the mould by the wire \( n \). Two atoms of water \( o \) and \( o' \), as bracketed \( 1 \) and \( 2 \), are shown to exist before the electric current passes; and two atoms, one of water \( o' \), bracketed \( 1' \) and one of oxide of copper \( e \), exist after the action.

On the other hand, an atom of copper \( e \) has come into the solution; and, on the other hand, the atom of hydrogen \( h \), belonging to the second atom of water, is set free and rises in the form of gas. The explanation is to show that oxygen is liberated where the current enters, and combines there in its nascent state with copper; it would not have combined, for instance, with gold or platinum. We might easily extend this symbolical figure, and show how that, when free sulphuric acid is in the solution, the oxide of copper on its formation combines with this acid to produce the sulphate of copper required; and how, when free sulphate of copper is present, the hydrogen, instead of being freed in the form of gas, combines with oxygen of the oxide of copper, and liberates the metal which in its nascent state is deposited on the mould, and produces the electrolyte copy of the same. One battery cell is sufficient for working in this way in copper; it is increased in size in proportion to the size of the object operated upon. And, although for small objects, such as medals, a vertical arrangement will act very well; for large objects it has been often found of great advantage to adopt a horizontal arrangement, placing the mould beneath the copper-plate. The varying density of a still solution in the vertical arrangement is not without its effect upon the nature of the deposit, both on its character and its relative thickness. This has been in some instances elaborated, and the advantage of the vertical method retained by keeping the solution in motion, either by stirring or by a continuous flow of liquid.

We have described principally Daniell's battery as the generating cell in electro-metallurgical operations; but Mr. Smee's more simple arrangement of platinized silver and zinc, excited with diluted sulphuric acid, has been found in practice more economical and convenient.

Fig. 263 is a Smee's cell; a vessel of wood, glass, or earthenware contains diluted sulphuric acid, one in eight or ten, a platinized silver plate \( s \), sustained by a piece of wood \( w \), with a plate of zinc \( zz \) on each side, so as to turn to useful account both sides of the silver plate. The zinc plates are connected by the binding screw \( b \). Platinization consists in applying platinum in fine powder to the metallic surface. When hydrogen is liberated by ordinary electric action upon a surface so prepared, it has no tendency to adhere or cling to it; but it at once rises, and in fact gets out of the way, so that it never, by its presence or lingering, interferes with the prompt and ready continuance of the electric action; and in this way the amount of supply is well kept up.

Platinization is itself another illustration of working in metal by electricity. A few crystals of chloride of platinum are dissolved in diluted sulphuric acid. A voltaic current is made to enter this solution by a plate of platinum, and to come out by a silver plate. Two or three Daniell's or Smee's cells are necessary for the operation. The chloride of platinum is decomposed, and the metal is deposited upon the silver plate; not, however, in the reguline compact form, as in the ease of copper, but in a state of black powder in no way coherent. Thereafter also an illustration of the different behavior of metals under analogous circumstances. Copper is of all metals the most manageable; platinum is among the more unmanageable.

Mr. C. V. Walker has, with great advantage, substituted graphite for silver. The material is obtained from gas retorts, and is cut into plates a quarter of an inch thick, or thicker, when plates of a large size are cut. He platinizes these plates in the usual way as above described, and deposits copper on their upper parts, also by electrolyte process, and solders a copper slip to the electrotype copper, in order to make the necessary connection.

With the exception of silver and gold, copper is the metal which has been most extensively worked by these processes.

Seals are copied by obtaining impressions in sealing-wax, pressing a warm wire into the edge for a connection; rubbing black-lead over the wax to make the surface conductive; fastening a slip of zinc to the other end of the wire; wrapping the zinc in brown paper, and putting the whole into a tumbler containing sulphate of copper, a little salt-water having been poured into the brown paper cell.

Plaster of Paris Medallions may be saturated with wax or stearine, and then treated, if small, like seals; if large, in a distinct trough, as in fig. 261. In this case the copy is in intaglio, and may be used as a mould for obtaining the facsimile of the cast. More commonly, the cast is saturated with warm water, and a mould of it taken in wax, stearine, or gutta percha. This is treated with black-lead, and in other respects the same as seals.
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Wood-cuts are treated with black-lead, and a copper reverse is deposited upon them. This is used as a mould to obtain electrotype duplicates, or as a die for striking off duplicates.

Stereotype Plates are obtained in copper by taking a plaster copy of the type, treating it plater fashion, depositing a thin plate of copper upon it, and giving strength by backing up with melted lead.

Old Brasses may be copied by the intervention of plaster.

Embossed cards or paper may be copied by first saturating with wax and then using black-lead.

Fruit may be copied by the intervention of moulds, or may be covered with copper.

Leaves, twigs, and branches may have copper deposited upon them. The same for statuettes, busts, and statues.

Leaves and flowers are furnished with a conducting surface by dipping them into a solution of phosphorus in bisulphuret of carbon, and then into a solution of nitrate of silver. Silver is thus released in a metallic state upon their surface.

Plaster busts, &c., have been copied in copper, by first depositing copper on the plaster prepared for this operation; when thick enough, the original bust is destroyed, the copper shell is filled with sulphate of copper, as in fig. 201, and copper is deposited on its inner surface till of sufficient thickness; the outer shell is then removed. Trunks and vessels of capacity do not appear to have been profitably multiplied by electrotyping.

Plates have been prepared for the engraver to work on by depositing copper on polished copper-plates, and removing the deposits when thick enough.

For the multiplication of engraved copper-plates, the electrotyping process has been very extensively adopted. A reverse of the plate is first obtained by the deposition of copper; this serves as a mould, from which many copies of the original plate are obtained by depositing copper upon it, and then separating the two. The mode practised by the Duke of Leuchtenberg is to print from an engraved plate on very thin paper with a mixture of resin of Damara, red oxide of iron, and essence of turpentine. While the impression is wet, the paper face downwards is pressed upon a polished plate of copper. When dry the paper is washed away, and the impression remains. An electrotype copy from this is obtained in intaglio, and is fit for the use of the printer.

GALVANOGRAPHY is a picture drawn originally in varnish on the smooth plate, and then treated in a similar way to the above.

The plates on rollers used by calico printers have been multiplied like engraved plates.

GlypOGRAPHY is a name given by Mr. Palmer to his process. He blackens a fair copper-plate with sulphuret of potassium, covering it uniformly with a coating of wax and other things, then draws the design through the wax with fine tools. From the plate thus prepared, an electrotype is taken in the usual way, and is backed up and mounted as an electro-glyphic cast to print from as from a wood block. For a stereo-glyphic cast to work from as a stereotype plate, a plaster copy is taken of the original drawing, the high lights are cut out, and then an electrotype copy is made.

Electro-tint is done by drawing with wax or varnish any design on a fair copper-plate, and making an electrotype copy for the printer's use.

Fern-leaves, &c., are copied by being laid on a sheet of soft gutta percha, pressed into the surface by a smooth plate to which pressure is applied, and then removed in order to subject the gutta percha mould to the electrotyping process. This is Nature Painting, which see.

M.M. Auer and Worring have copied lace, embroidery, flowers, leaves of trees, entire plants, fossils, insects, &c., in their natural relief, by laying the objects upon a plate of copper, after having soaked them in spirits of wine and turpentine so as to fix them. A plate of clean lead is laid over, and, on being pressed, an intaglio copy is produced on it of the object. From this an electrotype is obtained.

Undercut medallions, &c., are copied in elastic moulds made of treacle and glue in the proportions of 1 to 4. Masks and busts may also be obtained in such moulds.

Electro-cloth was made by saturating the fibre of canvas or felt, making it conductorous in the usual way; it was proposed in place of tarpanuels as a water-right cover.

Retorts and crucibles, &c., of glass or porcelain, have been successfully coated with electrotyping copper by first varnishing or otherwise preparing the surface to retain the black-lead, and then treating them as usual.

Soldading copper surfaces has been accomplished by galvanic agency. The ends to be united are placed together in the solution of sulphate of copper, and connected with the battery as for ordinary deposition. Parts not included in the process are protected off by varnish; copper is then deposited so as to unite the separate pieces into one.

Iron may be coated with copper. But here a new feature comes into view. Sulphuric acid leaves the copper of the sulphate, combines with iron, and deposits copper on
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Its surface without the aid of the volatile apparatus. The iron surface is imperfectly covered with copper; no firm perfect deposit occurs. In order to obtain solid deposits of copper on iron, it is necessary to use a solution that has no ordinary chemical reaction upon iron. Cyanide of copper is used, which may be obtained by dissolving sulphate of copper in cyanide of potassium. This solution requires to be raised to and retained at a temperature not greatly below 200°, in order to give good results.

Electro-zincing is applied to surfaces of iron, in order to protect them from corrosion. A solution is made of sulphate of zinc, which is placed in a trough, fig. 261. Two or three battery cells are required. The iron to be zinced is connected with the zinc end of the battery, and a plate of zinc with the copper end. Voltaic brass does not appear to have been obtained in a solid distinct form, but has been successfully produced as a coating upon a copper surface. Separate solutions are made of sulphate of copper and of sulphate of zinc in cyanide of potassium. The two solutions are then mixed, and placed in a decomposing trough. Two or three cells of a battery are used, and a brass plate connected with the copper end. An electrote copper medal or other prepared surface is connected with the zinc. Brilliant and perfect brass soon appears, and will deposit slowly for some hours; but after a while the character of the solution changes, and copper appears in place of brass.

This hasty glance at the leading applications of this art will give an idea of its utility. It also enters into play in cases where least suspected. Pins were tinned by electrote long before the art was known. Brass pins are thrown into solution of tin in cream of tartar, and are unchanged; but when a lump of tin is thrown among them, a voltaic pair is formed, and tin is deposited on all the brass. Any stray pins detached from the mass, escape the influence. Space would fail us were we to go through the list of crystalline and of simple bodies formed by these processes; as for instance, octahedral crystals of protocide of copper; tetrahedral crystals of protochloride of copper; octahedral crystals of sulphide of silver; crystals of substrate of copper; bisulphate carbonate of copper, and others too numerous to name, have all been formed by slow voltaic actions. The alkaline metals, potassium, sodium, &c., were first obtained by Davy in the galvanic way; magnesium, barium, aluminium, calcium, &c., are obtained by M. Bunson by operating upon the chlorides of these metals either in solution or in a state of fusion.

Electro-etching is produced at the place where the current enters the decomposing trough, as at the copper-plates c of fig. 261. A plate of copper is prepared as if for the graver; its face is then covered with an etching ground of asphalt, wax, black pitch, and Burgundy pitch; and its back with varnish. The design is then traced through the etching ground with a fine point; the plate is then placed in the trough b, containing either sulphate of copper or simply diluted sulphuric acid, and connected with the copper of the battery. After a few minutes it is removed, and the fine lines are stopped out with varnish; it is then replaced, and again, after a few minutes, is removed, and the darker shades are stopped out; the parts still exposed are again subjected to the action, and the etching is complete. When the ground is removed, the design will be found etched upon the copper-plate, ready for the printer.

Daguerreotype etching is a delicate operation, and requires much care. The solution employed by Professor Grove was hydrochloric acid and water in equal parts, and a battery of two or three cells.

Platinized silver is used in face of the daguerreotype, instead of copper. The result comes out in about half a minute. An oxchloride of silver is formed, and the mercury of the plate remains untouched.

A Photo-galvano-graphic Company has been formed in London for carrying out the process of Paul Previde. He makes solutions of bichromate of potash in glue water, or in solution of gelatine, instead of in pure water. He then treats the glass or plate with these, and in the usual way takes a picture. He washes the gelatine picture with water, or solution of borax or carbonate of soda, which leaves the picture in relief; when developed, he washes with spirits of wine, and obtains a sunk design. The surfaces thus prepared, or moulds made from them in one or other of the modes already described, are placed in a galvano-plastic apparatus for obtaining an engraved plate from which to print. See Photographic Engraving.

The Duke of Leuchtenberg prepares a plate for etching by leaving the design on the ground, and removing the ground for the blank parts. When his electroyte operation is complete, the design is in relief instead of being in intaglio, as in ordinary etching.

Metallo-chromes consist of thin films of oxide of lead, deposited sometimes on polished plates of platinum, but most commonly on polished steel plates. The colors are most brilliant and varied. Nobili is the author of the process.

A saturated solution of acetate of lead is prepared and placed in a horizontal trough. Three or four battery cells are required. A steel plate is laid in the acetate of lead with its polished surface upward, and is connected with the copper of the battery. If a wire is connected with the zinc end of the battery, and held over the steel plate in the solution, a
series of circles in brilliant colors arises from the spot immediately beneath the wire, and expands and spreads, like the circles when a stone is thrown into a pond. Silver-blond is the first color; then fawn-color, followed by the various shades of violet, and indigos and blues; lake, blush lake, green and orange, greenish violet, and passing through reddish yellow to rose-lake, which is the last color in the series.

According to the shape of the metal by which the current enters—be it a point, a slip, a cross, a concave, or a convex disc—so is the form of the colored figure varied. And if, in addition to this, a pattern in card or gutta percha is cut out and interposed between the two surfaces, the action is intercepted by the portions not removed, and the design is produced on the steel plate, in colors, that may be greatly varied, according to the duration of the experiment. The different colors are due to the different thicknesses of the thin films of peroxide of lead.

M. Becquerel proposed the deposit of peroxide of lead, and also the red peroxide of iron, for protecting metals from the action of the atmosphere. For the latter, protosulphate of iron is dissolved in ammonia solution, and operated upon by two or three batteries.

The most important application of electro-metallurgy in the arts has been for plating and gilding, which is most extensively carried on both at home and abroad. Results that were unattainable, and others attainable only at great cost, are readily produced by this mode of manipulating. The liquids most in use are the cyanide solutions, first introduced by Messrs. Elkingtons. They are prepared in various ways. Cyanide of potassium is added carefully to dilute solution of nitrate of silver; and the white deposit of cyanide of silver is washed, and then dissolved in other cyanide of potassium; or lime water is added to the nitrate solution, and the brown deposit of oxide of silver is washed, and, while moist, is dissolved in cyanide of potassium; or common salt is added to the nitrate solution, and the white deposit of chloride of silver is washed and dissolved in cyanide of potassium. Or a solution of cyanide of potassium is placed in the trough b, fig. 261; and the current from three or four cells is passed into it from a silver plate at c, which combines with and is dissolved into the liquid, converting it into a cyanide of silver solution. To prevent silver being abstracted by deposition at m, as the current leaves the trough, the metal at m is placed within a porous cell of cyanide solution, so as to limit the action.

Gold solution is obtained by dissolving the anhydrous peroxide of gold in cyanide of potassium, or by treating chloride of gold with cyanide of potassium, or by using a gold plate and a voltaic current with a solution of cyanide of potassium in the same way as described for silver; and allowing the action to continue until the solution is sufficiently strong of gold. With these solutions electro-plating and gilding are readily accomplished. There are other solutions more or less valuable, which will be found in the books that treat upon the subject.

Fig. 266 is an arrangement for operations on a small scale. The vessel a b, containing

the gold solution, rests over a small stove or spirit-lamp. The objects to be gilt are suspended by wires to the conducting rod d, in connection with the zinc end of the battery; and the gold wire or plate e is connected with the other end. A temperature of from 100° to 200° is desirable; the higher temperatures require fewer battery cells; with the highest, one will suffice. The solution of course evaporates under the influence of heat; and distilled water must be added to supply the loss, before each fresh operation.

Plating and gilding is successfully, and, in point of economy, advantageously carried on at Birmingham, in more than one manufactory, by means of magneto-electricity. In the article on Electric-Telegraphy, will be found a description of this form of electric force, and the means by which it is produced. An electro-magnet is set in motion in front of the poles of a permanent magnet, in such a manner that the soft iron core of the electro-magnet becomes alternately a magnet and not a magnet; in the act of becoming a magnet, it raises up a current in one direction in the wire with which it is wound; in the act of ceasing to be a magnet, it raises up a current in the reverse direction. The ends of the wire

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are led away and insulated. The instrument is fitted with a commutator, so adjusted that it collects the currents from the ends of the wire, and guides them in a uniform direction into the vessel that contains the solution and articles to be gilded or plated. In practice, a single machine consists of many electro-magnets grouped together, and many powerful magnets for exciting them; by which means a continuous flow of a large amount of electricity is obtained. Fig. 207 is an illustration of such an arrangement as adapted by Mr. Wool-

rich: a a a are four clusters of permanent steel magnets, seen from above; b b b b b is the frame-work of the machine; e e e e are four bars of soft iron, wound with large size insulated copper wire; d is a circular disc, on which they are mounted and which rotates on a vertical axis, of which f shows the upper end; e is the commutator, from which two wires are led off to the solution to be operated upon. The permanent magnets are U-shaped; one pole only of each bundle is visible; the other is beneath the disc d, and its freight of electro-magnets e e, &c. The axis is set in rotation by a strap passing over the drum of a shaft of the steam-engine, that does the ordinary work in a factory; and the disc carries the electro-magnets between the poles of the permanent magnets, and exposes them to the most favorable action of these poles. The number of coils and magnets vary in proportion to the work required. By this arrangement not only does each coil pass under the influence of many magnets, but each magnet acts successively on many coils; and a proportionate supply of electricity is the result.—C. V. W.

ELECTRO-MOTIVE ENGINES. Electro-magnetism undoubtedly affords an almost unlimited power. An electro-magnet may be constructed which shall have a lifting power equal to many tons. It is probable that there are limits beyond which it would not be possible to increase the power of electro-magnets; those limits have not yet been reached; but supposing them to be attained, there is nothing to prevent the multiplying of the number of electro-magnets in the arrangements. It may be stated, in connection with this part of the subject, that from experiments made with Hoarder's magnetometer, it appears that the development of magnetism in iron observes some special peculiarities. These may be thus stated:—With the same electro-magnet there is, as the voltaic pairs in the battery are increased, a gradual increase of magnetic force. With from one to seven elements there appears an average excess of 31 lbs.; after this point, with the increase of battery power, by the addition of pair after pair of zinc and platinum elements, the production of power bears a decreasing ratio to the power employed, and at last, the addition of five elements was not found to produce an increase of effect equivalent to the value of one element. In all experiments, therefore, on electro-magnetic machines, the experimentalist has first to determine the utmost power which the soft iron is capable of assuming, in relation to—
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1st. The number of coils of wire on the iron; and 2d. The number of elements employed in the exciting source—the voltaic battery. The length of the iron and its thickness are also points demanding special considerations from the constructor of an electro-magnetic machine.

There remains now to examine the production of the power, Electro-Magnetism. The electro-mechanism is dependent upon his battery, in the same way as a steam-engine is dependent upon his fire and his boiler, for the production of mechanical effect. Voltaic batteries vary in their effects, and hence arise statements which differ widely from each other, as to the result obtained, by the destruction (a change of form) of a given quantity of metal in the battery. Dr. Botto states, that 45 lbs. of zinc, consumed in a Grove's battery, are sufficient to work one-horse power electro-magnetic engine for twenty-four hours.

Mr. Joule says the same results would have been obtained, had a Daniell's battery been used, by the consumption of 75 lbs. of zinc.

It is impossible, on the present occasion, to enter into the theory of the voltaic battery, or to describe the varieties of arrangement which have been adopted for generating (developing) electrical force in the form of a current, with the greatest effect, at the smallest cost.

On this point the evidence of Jacobi may be quoted:—"With regard to the magnetic machine, it will be of great importance to weaken the effects of the counter current, without at the same time weakening the magnetism of the bars. It is the alternate combination of the pairs of plates in the voltaic pile, which permits us to increase the speed of rotation at will. We know the magnetic power of the current is not sensibly augmented by increasing the number of the piles of plates, but the counter current is considerably weakened by its being forced to pass through a great many layers of liquid. In fact, in using twelve voltaic pairs, each half a square foot, instead of four copper troughs, each with a surface two square feet, which I had hitherto used, the speed of rotation rose at least 250 or 300 revolutions in a minute."

Mechanical force, whether obtained in the form of man-power, horse-power, steam-power, or electrical-power, is the result of a change of form in matter. In the animal, it is the result of muscular and nervous energy, which is maintained by the due supply of food to the stomach. In the steam-engine, it is the result of vapor pressure, which is kept up by the constant addition of fuel to the fires under the boilers. In the magnetic machine, it is the result of currents circulating through wires, and these currents are directly dependent upon the chemical change of zinc or of some other metal in the battery. Then,

Animal power depends on food.
Steam power depends on coal.
Electrical power depends on zinc.

An equivalent of coal is consumed in the furnace—that is, it unites its carbon with oxygen to form carbonic acid, and its hydrogen with oxygen to form water, and during this change of state the quantity of heat developed has a constant relation to the chemical action going on.

Mr. Joule has proved by a series of most satisfactory experiments, that "the quantity of heat capable of increasing the temperature of a pound of water by one degree of Fahrenheit's scale is equal to, and may be converted into, a mechanical force capable of raising 338 lbs. to the perpendicular height of one foot."

Mr. J. Scott Russell has shown that in the Cornish boilers, at Huil Town and the United Mines, the combustion of one pound of Welsh coal evaporates of water, from its initial temperature, 10°38' and 10°48' respectively. "But," says Mr. Joule, "we have shown that one degree is equal to 883 lbs. raised to the height of one foot. Therefore the heat evolved by the combustion of one pound of coal is equivalent to the mechanical force capable of raising 9,584,206 lbs. to the height of one foot, or to about ten times the duty of the best Cornish engines."

Such are the conditions under which heat is employed as a motive power. An equivalent of zinc is acted on by the acid in the cells of the battery, and is oxidized thereby. In this process of oxidation a given quantity of electricity is set in motion; but the quantity available for use, falls very far below the whole amount developed by the oxidation of the zinc. The electricity, or electrical disturbance, is generated on the surface of the zinc; it passes through the acidulated fluid to the copper plate or platinum plate, and in thus passing from one medium to another, it has to overcome certain mechanical resistances, and thus a portion of the force is lost. This takes place in every cell of the voltaic arrangement, and consequently the proportion of zinc which is consumed, produces any final mechanical result, is considerably greater than it should be theoretically.

Joule gives as the results of his experiments, the mechanical force of the current produced in a Daniell's battery as equal to 1,106,100 lbs. raised one foot high, per pound of zinc, and that produced in a Grove's battery as equal to 1,843,000 lbs. raised one foot high, per pound of zinc.

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It need scarcely be stated, that this is infinitely above what can be practically obtained. A great number of experiments, made by the Author some years since, enabled him to determine, as the mean average result of the currents produced by several forms of battery power, that one grain of zinc, consumed in the battery, would exert a force equal to lifting 80 lbs. one foot high. Mr. Joule and Dr. Scevashby thus sum up a series of experimental results: "Upon the whole, we feel ourselves justified in fixing the maximum available duty of an electro-magnetic engine, worked by a Daniell's battery, at 80 lbs. raised a foot high, for each grain of zinc consumed." This is about one-half the theoretical maximum duty. In the Cornish engines, doing the best duty, one ton of coal gave raised 143 lbs. one foot high. The difference in the cost of zinc and coal need scarcely be remarked on. The present price of the metal is £35 per ton, and coal can be obtained, including carriage to the engines, at less than £1 per ton; and the carbon element does two-thirds more work than can possibly be obtained from the metallic one.

By improving the battery arrangements, operators may eventually succeed in getting a greater available electrical force. But it must not be forgotten, that the development of any physical force observes a constant law. Whether in burning coal in the furnace, or zinc or iron in the battery, the chemical equivalent represents the theoretical mechanical power. Therefore the atomic weight of the carbon atom being 6, and that of the zinc atom being 32, it is not practicable, under the best possible arrangements, to obtain any thing like the same mechanical power from zinc which can be obtained from coal. Zinc burns at an elevated temperature; in burning a pound of zinc there should be obtained, as heat, the same amount of mechanical power which is obtained as electricity in the battery. The heat being more easily applied as a prime mover, it would be far more economical to burn zinc under a boiler, and to use it for generating steam-power, than to consume zinc in a voltaic battery for generating electro-magnetic power.

**ELECTRO-PLATING AND GILDING IRON.** Professor Wood, of Springfield, Mass., in a paper which he has communicated to the *Scientific American*, recommends the following as useful recipes for the electro-metallurgist. He says: "I believe it is the first time that a solution for plating direct on iron, steel, or Britannia metal, has been published. In most of the experiments I have used Snee's battery; but for depositing brass I prefer a battery fitted up as Grove's, using artificial graphite—obtained from the inside of broken coal-gas retorts—in the place of platinum. With one large cell, (the zinc cylinder being 8 x 8 inches, and excited with a mixture of one part sulphuric acid and twelve parts water, the graphite being excited with commercial nitric acid,) I have plated six gross of polished iron buckles per hour with brass. I have also coated type and stereotype plates with brass, and find it more durable than copper-facing."

To Prepare Cyanide of Gold.—1. Dissolve 1 oz. of pure silver in 2 oz. of nitric acid and 2 oz. of hot water, after which add 1 quart of hot water. 2. Dissolve 5 oz. of the cyanide of potassium in 1 quart of water. To the first preparation add by degrees a small portion of the second preparation, until the whole of the silver is precipitated, which may be known by stirring the mixture and allowing it to settle. Then drop into the clear liquid a very small quantity of the second preparation from the end of a glass rod; if the clear liquid is rendered turbid, it is a proof that the whole of the silver is not separated; if, on the other hand, the liquid is not altered, it is a proof that the silver is separated. The clear liquid is now to be poured off, and the precipitate, which is the cyanide of silver, washed at least four times in hot water. The precipitate may now be dried and bottled for use. To Prepare Cyanide of Silver.—1. Dissolve 1 oz. of fine gold in 14 oz. of nitric acid and 2 oz. of muriatic acid; after it is dissolved, add 1 quart of hot water, and precipitate with the second preparation, proceeding the same as for the cyanide of silver. To Prepare Cyanides of Copper and Zinc.—For copper, dissolve 1 oz. of sulphate of copper in 1 pint of hot water. For zinc, dissolve 1 oz. of the sulphate of zinc in 1 pint of hot water, and proceed the same as for cyanide of silver. The electro-plater, to insure success in plating upon all metals and metallic alloys, must have two solutions of silver; the first to whiten or fix the silver to such metals as iron, steel, Britannia metal, and German silver; the second to finish the work, as any amount of silver can be deposited in a reguline state from the second solution. First, or Whitening Solution.—Dissolve 24 lbs. (troy) of cyanide of potassium, 8 oz. carbonate of soda, and 5 oz. cyanide of silver in one gallon of rain or distilled water. This solution should be used with a compound battery, of three to ten pairs, according to the size of the work to be plated. Second, or Finishing Solution.—Dissolve 4 oz. (troy) of cyanide of potassium, and 1½ oz. of cyanide of silver, in 1 gallon of rain or distilled water. This solution should be used with one large cell of Snee's battery, observing that the silver plate is placed as near the surface of the articles to be plated as possible.—N. B. By using the first, or whitening solution, you may insure the adhesion of silver to all kinds of brass, bronze, red cock metal, type metal, &c., without the use of mercury, which is so injurious to the human system. To Prepare a Solution of Gold.—Dissolve 4 oz. (troy) of cyanide of potassium, and 1 oz. of cyanide of gold, in 1 gallon of rain or distilled water. This solution is to be used warm, (about 90° Fahr.,) with a battery of at least
twice cells. Gold can be deposited of various shades to suit the artist, by adding to the solution of gold a small quantity of the cyanides of silver, copper, or zinc, and a few drops of the hydro-sulphuret of ammonium.

ELECTRO-SORTING APPARATUS. M. Froment has devised an apparatus for the separation of iron from matters by which it may be accompanied. The apparatus consists of a wheel carrying on its circumference eighteen electro-magnets. The iron ore reduced and pulverized is spread continually upon one of the extremities of a cloth drawn along with it, and passed under the electro-magnets in motion. * The iron in the ore, which has of course been brought into a magnetic state by any of the processes by which this may be effected, is separated by the magnets, and the impurities carried onward. See De la Rive's *Electricity.*

ELECTRO-TELEGRAPHY. It would far exceed our limits were we to attempt the most hurried sketch of the history of this art; we shall therefore content ourselves with illustrating the leading doctrines that have been realized in the telegraph systems which are most in favor in the time in which we write.

Locked up, as it were, in all bodies, is a large store of electric force, the equilibrium of which is disturbed in a greater or less degree by a variety of causes, some extremely simple, others more complex; and, according as one or other cause is in operation, the conditions under which the electric force is manifested vary; some conditions being very unfavorable, and others very favorable to the object in view.

Friction is a well-known means of producing electric effects. Amber (in Greek, *elektron*) was the first substance on which they were noticed in a special manner, and hence the name. Light bodies, such as gold leaf, or feathers, are attracted by rubbed amber; the leaf gold is quickly repelled again, the feathers not so readily. In due course it was discovered that this difference of behavior is due to the gold conducting electricity, and the feathers not so; the one allowing the force to diffuse itself about it, the other receiving and retaining it only in or near the points of contact; if the former property were universal, it would be impossible to collect electricity; if the latter, it would be impossible to get rid of it. *Conduction* is well illustrated and turned to useful account in the iron and copper wires, by which distant telegraph stations are connected with each other; *insulation,* by the glass or porcelain articles with which the said conducting wires are suspended to the poles above ground, and by the gutta percha with which the subterraneean or submarine wires are covered.

The rapidity with which electric force traverses conductors depends upon the circumstances under which the conductors are placed; in one case, as in that of wire suspended in the air, the electric force has little else to do than to travel onward and be discharged from the far end of the wire; in the other case, as in that of buried wire, it has to disturb the electric equilibrium of the gutta percha as it travels onward, and thus suffers considerable retardation. The greatest recorded velocity of a signal through a suspended copper telegraph wire, is 1,752,800 miles per second, by M. Hipp; the lowest velocity through a buried copper wire, 750 miles per second by Faraday. Intermediate velocities are recorded, for which the nature of the wire or the conditions under which it was placed were different. Wheatstone found the velocity of electricity under different conditions from the above to be 298,000 miles per second. The wire was copper, and was wound on a frame. The electricity that was employed by Mr. Wheatstone in these experiments was obtained from the friction of glass against an amalgam of tin. The various velocities are due partly to the conditions under which the conducting wire is placed, and partly, no doubt, to the varied properties of electricity from various sources. And the very different methods of reading off the velocities in this and in other cases may have an influence over the respective values.

Electricity is obtained from other sources than friction with so much greater facility, and in forms so much more applicable and manageable for telegraphic purposes, that frictional electricity has not been applied in real practice. It must not, however, be passed over in this place, because one of the earliest telegraphs, perhaps the very first in which a long length of wire was actually used, was actuated by this form of electricity. In 1816, Mr. Ronalde established, in the grounds attached to his residence at Hamerencrsmith, eight miles of wire suspended by silk to dry wood, besides 175 yards of buried wire in glass tubes embedded in pitch and enclosed in troughs of wood. He obtained his electricity from a common electrical machine, and his signals from the motion of light bodies, balls of elder pith, produced under circumstances analogous to those to which we have already referred. At the far end of this telegraph wire two pith balls were suspended close together. Electricity applied to the home end of the wire at once diffused itself throughout the conducting system, including the pair of light balls. Just as we have seen gold leaf recede after having approached rubbed amber, and acquired an electric charge, so the pith balls, each being charged with electricity, derived from the same source, recede from each other; and this in obedience to the fundamental laws of static electricity, for which we must refer readers to treatises on the subject. Here, then, we have one solitary signal. The manner in which Mr. Ronal-
turned it into language was ingenious. He pressed time into his service, and by combining time and motion he obtained a language. He provided a clock movement at each station; the clocks were so regulated as to be synchronous in their movements; each of them carried, in lieu of a hand, a light disc, having the letters of the alphabet and other signals engraved on it. The disc was hidden by a screen, in which was one opening. It is obvious that if the clocks were started together, and had uniform rates, the same letter at the same time would be visible through the openings in each case; so that the letter would pass seriatim and simultaneously before the respective openings. If absolute uniformity is difficult for long periods, it is practicable for shorter. The sender of a message watched the opening of his screen; the moment the letter approached that he desired to telegraph, he charged the wire with electricity, and the balls at the far station moved; the letter then visible there corresponded with the one at the home station, and was read off. The sender watched till the next letter he required came round, and so on.

Let us now pass on to some of the leading features of electro-telegraphy, as it has been realized of late years, and to a description of some of the telegraph instruments that are most in use.

Chemical action is the most fertile source of electricity. If a silver fork and a steel knife are connected together by a piece of wire, and the fork is thrust into a piece of meat, say a hot mutton chop, the moment an incision is made in the meat with the knife, electricity will pass along the wire, and continue to do so, while the above disposition of things remains. Upon the proper test being applied, the electricity is readily detected. This is the current form of electricity. The amount of force in circulation in this particular combination is not very great, and its power of travelling to a distance is not very high, but still it is quite capable of producing good signals, on a delicate arrangement of the needle instrument, (of which more hereafter,) with which in England we are so familiar.

The amount of electricity obtained by means of chemical action is increased to the required extent by a judicious selection of metals, and of the liquid or liquids in which they are immersed. Zinc is invariably used as one of the metals; it is represented by the iron of the knife in the above experiment. Copper, silver, and platinum or graphite, (gas carbon,) is selected for the other metal. When the two metals are immersed in a same liquid, a mixture of sulphuric acid with salt-water, or fresh, is employed. When two liquids are used, they are separated by a porous partition; the zinc is usually placed in the sulphuric acid solution, and the other metal in a solution varying with the nature of the arrangements proposed. Zinc is naturally soluble in the acid solution in question; and would therefore waste away and be consumed at the expense also of the acid, unless precautions were taken to make it resist the ordinary action of the solvent. When zinc is dissolved in mercury it is not attacked, under ordinary circumstances, by sulphuric acid solution. Hence the plates of zinc employed in all good volatile combinations, as they are called, into which this acid, in a free state, enters, are protected by being well amalgamated; that is, they are dipped in a strong acid mixture and well washed; and are then dipped into a mercury bath, and are placed aside to drain. The operation is generally repeated a second time; and, in the best arrangements, the further precaution is taken of standing the zinc plate, while in the acid water, in some loose mercury, placed either in the bottom of the containing vessel, or in a gutta percha cell; by the latter arrangement, mercury is economized. In single liquid arrangements, it is desirable to select a metal that is not attacked by the acid. Copper has been extensively used, and is very valuable; but it possesses the defect of being slowly attackable. The waste, however, that it suffers in itself from this cause, is of small moment compared with certain secondary results, which terminate in the consumption of the acid and the zinc, and the destruction of the functions of the apparatus. Gold and platinum are free from these defects, but are too costly. Silver is to a great extent free from them, and has been much and successfully used, especially when platinized; that is, having its surface covered with finely divided powder of platinum. The corrosion from gas retorts, cut into plates, and similarly treated, forms with amalgamated zinc one of the cheapest and most effective combinations.

A single pair of plates, no matter what their character, is unable to produce a force that can overcome the resistance of a wire of any length, and produce an available result at a distant station; and hence a series of pairs is employed in the telegraphic arrangements. V (pp. 286, 288) represents a common mode of arranging a series of pairs of plates. It consists of a wooden trough made watertight, and divided into water-tight cells. The metals are connected in pairs by copper bands; each pair is placed astride over a partition, and all the zines face one way. When the plates (copper-zinc) are placed in, and the cells are filled up with pure white sand, and the acid water poured in, we have the very portable battery that was originally used by Mr. Cooke, and is still much employed in England. When batteries of a higher class are employed, the cells are distinct pots or jars; and great precautions are taken to prevent any conducting communication existing between the neighboring cells, save by means of the copper band. In the trough form there is a leakage and loss of force from cell to cell. The c or copper is the positive end of such a series, and the z...
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or zinc, the negative; and both are in a condition to discharge, either each to the other, by means of a wire led from one to the other, or each to the earth, one by a wire leading to the earth at the place where the battery stands, and the other by a long wire (say a telegraph wire) leading to the earth at a distant place. The resistance to be overcome is, in the former case, less; and the current of force in circulation is proportionately greater. Under whatever circumstances a wire takes part in promoting the discharge of an apparatus of this kind, the whole of the said wire is in a condition to indicate the presence of the force that is pervading it; and as the force may be presented to the wire in either of two directions, that is to say, the copper or the zinc, namely, the positive or the negative end of the battery, may be presented to the given end of the telegraph wire, the relative condition of the wire will be modified accordingly. Not only can the direction of this current force be inverted at pleasure, but it can be maintained for any length of time, great or small, and in either direction. This is accomplished by various mechanical arrangements, which are the keys, commutators, or handles of the various telegraph instruments, (of which more hereafter,) and are often the only part presenting any complexity about them. In fig. 268, the source of electricity, k, we have already described; the test-instrument for the abnormal state of the wire, that is to say, the telegraph proper, is the part A. The complex part, consisting of springs, cylinders, and studs, shown below A, is nothing more than the necessary mechanical arrangement for directing at pleasure the current from the battery, k, in either direction through the wire, and through the part A. By following the letters in the order here given, the course of the current may be traced from its leaving, say the positive or copper end of the battery, till its return to the zinc or negative end; c e' b w w u a z' b z. If a companion instrument were in any part of the circuit of the wire w w, it would correspond in its signals with the home instrument, fig. 268.

One of the properties possessed by a wire, during the act of discharging a voltaic battery, is to deflect a magnetized needle. If the two are parallel in the normal state of the wire, the needle is deflected this way or that, when the wire is in the abnormal state; and if the needle is very delicate, and a large enough amount of electricity is circulating through the wire, the needle reaches the maximum deflection of 90°. This is an extreme case, and cannot be approached in practice. Indeed, the deflection of any ordinary needle, under the action of an ordinary telegraph wire, would not be appreciable. But, as every foot of the wire has the same amount of reaction, we have merely so to arrange things that many feet—a long length of the wire—shall be made to react upon the needle at the same time, and thus the effect is multiplied in proportion to the length of wire so concentrated. This is managed by covering a considerable quantity of fine wire with silk or cotton, and winding it on a frame A, (fig. 268,) suspending the needle within the frame. Such an instrument is called, from its properties, a multiplier. It is seen at a glance that the wire of the multiplier is an addition over and above the length of the actual telegraph wire required for reaching the distant station, and thus it practically increases the distance to be traversed: its smallness adds to this. The multipliers commonly used add a resistance equal to six or seven miles of telegraph wire.
Let us now turn to the face of the instrument. Here we have a dial and an index, which is on the same axis as the magnetized needle above described, capable of being deflected to the right or left, and limited in its motion by ivory pins. We have a handle for working the mechanical part so connected that, as it moves to the right, it directs a current into the wire such that the needle moves to the right, and vice versa. An alphabet is constructed from the combination of these two elementary motions, one or more of either or both kinds of deflection being used for the various letters, as shown on the engraved dial. This is Cooke and Wheatstone's single needle instrument, fig. 269.

The form and character of their double needle instrument is shown in fig. 270. It is precisely a duplicate of the former; two handles, and their respective springs, studs, and cylinders, two multipliers, and two magnetized needles, with their external indexes, and two telegraph wires. One battery, however, is sufficient. One or more of either or both kinds of deflection of either or both needles, according to the code engraved on the dial, constitutes the alphabet. This instrument is very extensively employed; messages are sent by it with extreme rapidity.

Another property possessed by a wire conveying a current, is that of converting
soft iron, for the time, into a magnet. The attractive power, which can thus be given to, and withdrawn from, the soft iron at pleasure, is turned to useful account, either in producing direct mechanical action, or in liberating the detents of a clock movement. Here also the effect of the solitory wire is inappreciable, and many convolutions around the iron are necessary in order to obtain a useful result.

The simplest application of this principle is shown in Fig. 271. Here are two brass reels, filled with cotton-covered copper wire, in one length. They are hollow, and a U-shaped bar of iron passes through them, presenting its ends at the face turned toward us in the drawing. This bar becomes magnetic—forms what is called an electro-magnet—every time and as long as an electrical current circulates in the wire; and its ends become respectively north and south poles. A narrow plate of iron, an armature, as it is termed, is mounted on pivots in front of the ends or poles of the magnet; it carries a vertical stem upon which the hammer is fixed. Every time the iron bar is magnetic the armature is attracted, and the hammer strikes the bell. The spring or contact-maker for introducing the current of electricity into the circuit, is shown in front on the right-hand side. This is Mr. Walker's bell for signalling railway trains from station to station. The language consists of one or more blows. One, two, and three blows, are the signals for common purposes; half a dozen blows is the limit. The acknowledgment of a signal is its repetition. By a simple arrangement of an index, that moves in fellowship with the hammer, the eye, as well as the ear, may read the bell-signals.

Fig. 272 shows another application of the direct action of an electro-magnet in produc-
produce a mark, is such that it cannot conveniently be produced by the magnetic attraction derived from a current of electricity that has come from a far distant station in order to circulate in the coils of wire \( m \). This difficulty does not prevail in the signal-bells, fig. 271, which are, at most, not required to be more than eight or ten miles apart, and in which also momentum can be and is accumulated so as to conspire in producing the final result. Morse has, therefore, had recourse to a \textit{relay}; as he calls it. This, in principle, is pretty much the same thing as the instrument itself; but it has no heavy work to do, no marks to make; it has merely to act the part of a contact-maker or key; it can hence be made very delicate, so as to act well by such currents as would not produce any motion in the instrument itself. The batteries which furnish the electricity for doing the actual printing work in Morse's telegraph, are in the same station with the instrument itself. The office of the relay is to receive the signals from afar, and to make the necessary connections with the local battery and instrument so as to print off the signals on the paper in the usual way. It is obvious that the motions of the instrument and the relay are sympathetic, and that what a trained eye can read off from the one, a trained ear can read off from the other. The relays are constructed with much finer wire than is required for the instrument itself, so that the current circulating in them, although very low in force, is multiplied by a very high number, and becomes equal to the delicate duty required of it.

Fig. 273 is another illustration of the direct application of the electro-magnet without adventitious aid. It represents a detent of McCallum's Globotype for recording signals. The long tube contains small glass balls, which are retained therein by a detent attached to the armature of an electro-magnet. Every time the armature is attracted, one ball is liberated and runs down into a grooved dial, where it remains for inspection. One or more tubes and detents are used, according to the nature of the signal required. As applied to the signal-bell, (fig. 271,) three tubes are used—one charged with black balls, for indicating the number of bell strokes made; one with white balls, for indicating the bell-signals sent; one with spotted balls, for marking off the time in quarters of hours or intervals of less length. The balls, when liberated, all run into the same dial, and arrange themselves serially.

We may here refer to the case of another bell or alarum, in which the magnetic attraction derived from the current that arrives, is not equal to the mechanical work of striking a blow and sounding a bell, but which is able to raise a detent, that had restrained a train of wheels, and so allow the mechanism of the latter to do the work required. This arrangement is shown in Cooke and Wheatstone's alarum, fig. 274: \( i \) is the bell; \( m m \) is the double-headed hammer, which is in fact the pendulum, attached to the pallets \( f \), which work in a scope-wheel hidden in the figure, and in gear in the usual way with a coiled spring in the box \( d \), by the train \( r_4, r_5, r_6, r_7 \). The electro-magnetic part here, as in other instruments, is simple enough; \( a e \) is a lever moving on a centre above \( l \), having at one end an armature \( a \), facing the poles of the electro-magnet \( c \); and at the other end \( e \), a hook which faces the wheel \( r \), and by catching in a notch on its circumference, keeps the train at rest. But when a current circulates through the coils \( e \), the armature is attracted, the hook is raised, the train is liberated, and the pendulum-hammer vibrates and strikes a succession of blows. \( n \) is a support carrying a small spring, which reacts on the lever, and restores it to its normal position when the magnetism ceases. This alarum is used for calling the attention of telegraph clerks. It requires a little attention to keep up the proper adjustment between the spring on the one hand, and the magnetic attraction on the other.
The telegraph originally adopted and still largely used by the French Administration, is somewhat akin to the alarum just described. It has a train of wheels, a scape-wheel with four teeth, and a pair of pallets. There is, however, no pendulum; but the pallets are connected with the armature of an electro-magnet, in such a manner that, for each attraction or repulsion of the armature, the scape-wheel is liberated half a tooth; for an attraction and a repulsion, a whole tooth; so that four successive currents, producing of course four consecutive attractions and repulsions, produce a whole revolution of the scape-wheel. The axis of the latter projects through the dial of the instrument, (fig. 275,) and carries an arm

\[ a \text{ or } b, \text{ (fig. 276,) which, following the motion of the wheel, is able to assume eight distinct positions. The apparatus is generally double, as shown in the figure; and the signals are made up of the various combinations of the eight positions of each of the two arms. The arm is half black, the other half white. The position of the black portion is read off; the white portion is merely a counterpoise. When only one half of the dial, or one index, is in use, the combinations are shown by producing with the one index successively the positions of the two, whose combination makes the signal, always giving first the position of the left hand index, then that of the right. The handles shown in front are the contact-makers, and are so constructed that the position of the arm on the dial coincides with the position given to the handle. Fig. 276 is a front view of the two arms; part of the dial is supposed to be removed, so as to expose the four-toothed wheel already mentioned, and the pallets \( x \) and \( z \); which, in their movement to and fro, allow of the semi-tooth advances of the wheel.}

In these various applications of the electro-magnet, the armature has been of soft iron, and the only action of the electro-magnet has been to attract it. It has been withdrawn from the magnet after the electricity has ceased to circulate, either by its own gravity, by a counterpoise, or by a reacting spring. We now come to a telegraph that is well known and much used—Henley's magneto-electric telegraph, in which there is no reacting spring; and in which the movement or signal is produced by the joint action of attraction and repulsion, and the return to its normal state by the same joint action. Each pole of Henley's electro-magnet has a double instead of the single termination, that we have been considering in all preceding cases. A piece of soft iron, like a crescent, is screwed upon each of the poles; the horns or cusps of the respective crescents are facing and near to each other; and a magnetized steel needle is balanced between them. This arrangement is somewhat like the following ( \( \text{fig. 276,} \) ). So long as no current is circulating in the coils of the electro-magnet, the crescents are impasive soft iron, and no one point of either of them has more tendency than any other point to attract either end of the magnetized needle that is between them. But while a current is circulating, one of the crescents is endowed with north magnetic polarity, which is especially developed at its horns, and the other with south polarity. Suppose the horns of the
right-hand crescent are north poles, those of the left south poles, and the top end of the needle is north. Four forces will conspire to move the needle to the left. Its top will be attracted by the left-hand crescent and repelled by the right; its bottom will be repelled by the left, and attracted by the right. When this current ceases to circulate, the simple attraction between the magnetized needle and the soft iron of the crescent tends to retain it in a deflected position. This tendency is increased by a little residual magnetism, that is apt to remain in the best iron, notwithstanding every care in its preparation. In order, therefore, to restore the needle to its normal position, a short quick current in the reverse direction is given. These instruments are single or double. Only one kind of deflection of the needle is available for actual signals, the other motion being merely the return to the normal state. The single needle alphabet is composed of deflections of a short or a long duration; these are produced by holding on the current for an instant or for more than an instant; and the various combinations of short and long correspond to Morse's dot and dash system. The double needle alphabet consists of combinations of the deflection of either or both needles.

Fig. 277 shows Henley's instrument, and, in completing the description of it, we have to describe another source of electric current to which no allusion has been hitherto made. The electricity here employed is obtained neither by friction nor by chemical action, but by means of magnetism and motion. If a piece of metal is moved in the presence of a magnet, or a magnet is moved in presence of a piece of metal, a current of electricity is generated in the metal. The results are multiplied when the metal is a coil of covered wire; so that we have here the converse of the electro-magnet; in the one case electricity had produced magnetism, in the other magnetism produces electricity; hence the name magneto-electric telegraph. We have here a powerful set of steel magnets a a, all the north ends pointing in one direction, and bound together with a plate of iron, and all the south ends similarly arranged in the other direction. Facing each end, but not quite in front when at rest, is an electro-magnet proper, b b, consisting of the U-shaped iron rod and the coil of covered wire, as described in fig. 271. Each electro-magnet is mounted upon an axis. c is a short lever or key; on depressing this, the electro-magnet moves from its normal position in a region of lesser magnetic force, into a new position in the region of greatest magnetic force, and thus is the double condition, enumerated above, complied with; the copper wire is moved in the presence of a magnet, and this under the most favorable conditions; and the U iron, rising from a feeble to a strong magnet, its lines of magnetic force move in presence of the copper wire. Just as a current, coming from a long distance, had to be received in Morse's arrangement (fig. 272) in an electro-magnet of a long coil of fine wire, so as to be much multiplied in order to do its work, so here a magneto-electric current, that has to be sent to a long distance, must be generated in a long coil of very fine wire in order to have electro-motive force sufficient to overcome the resistance opposed to it. In like manner the electro-magnets of the instrument b, in which it is received at the far-off station, have the same multiplying characteristics. The magneto-electric current exists only during the motion of the electro-magnet in front of the steel magnets, and this motion must be rather brisk, or the change of place is slow and the current feeble; but the current ceases with the motion. The needle, however, remains deflected from causes to which we have already referred, and if the hand is gently raised, so that the coils return slowly to their normal position, the needle will remain deflected; but, if the hand is so removed that the coils return quickly from the region of greatest to one of lesser magnetic force, a reverse current of lesser force than the original is generated, which releases the needle from its deflected position and restores it to its normal place, ready for making the next signal. In a recent form of this instrument Mr. Henley has obviated the necessity of moving the electro-magnets, still retaining the same fundamental principles. He uses a set of large U-shaped permanent magnets, and places the electro-magnet in the space between the branches of the permanent magnet, and so that the four poles of the two mag-
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nets, the permanent and the electro, shall be flush with each other, or in the same plane. A couple of iron armatures are mounted on a disc in front of the magnets. The disc has a motion on a centre; the armatures are curved or crescent-shaped. Their form is so adjusted to the relative positions of the poles of the respective magnets, that, in their normal or ordinary position, one crescent connects the N. pole of the magnet with one, say the upper pole of the electro-magnet, and the other crescent connects the S. pole of the permanent magnet with the lower pole of the electro-magnet. On pressing a key the disc moves, and the armatures so change in position that the N. pole of the magnet is connected with the lower, and the S. pole with the upper poles of the electro-magnet. By this arrangement the polarity of the electro-magnet is reversed at pleasure, and in its transition from being a magnet with poles in one direction, to becoming a magnet with poles in the reverse direction, an electric current is generated in the wire with which it is wound, and the direction of the current is this way or that, according as the transition is from this direction of polarity to that. This form of magneto-electric machine allows of larger electro-magnetic coils being used, and gives the manipulator comparatively very little weight to move in signalling.

We have shown how an electric current generates magnetism, and how magnetism generates another electric current; it would follow logically that one electric current should therefore generate another electric current; for the magnetism produced by a current circulating in one wire, must have all the properties of magnetism, and among them that of producing another current in another wire; and so it is. A few convolutions of a large-sized wire are coiled round an iron rod; and outside the larger wire is a very great length of finer wire. The current from the battery is called the primary current in this arrangement; and the moment it begins to circulate in the large wire, it magnetizes the iron and generates a current, called secondary, in the fine wire, which is able to penetrate to a very great distance. When the primary current ceases, magnetization ceases, the lines of magnetic force disappear, and a reverse secondary current is produced. This was the method proposed for obtaining the secondary current for traversing the Atlantic Ocean from Ireland to Newfoundland. The large wire is not necessarily first coiled on; in the coils for the Transatlantic telegraph it was coiled outside. Nor is the presence of iron essential to obtaining secondary currents.

It will have been noticed in all the arrangements which have hitherto been described, that the signals are produced by motions,—that the electric current, on reaching the far station, is multiplied by being directed through many convolutions of wire, and is made to act upon either a piece of soft iron or a piece of magnetized steel, and to move them, the motion being turned to account directly, or by the intervention of mechanism. We have yet another property of electricity, that has been very successfully applied to the production of telegraphic signals by Mr. Bain, in his electro-chemical telegraph. If a current of electricity is led into a compound fluid body, say into water, by one wire and out of it by another wire, the body is decomposed into its constituent elements, one of which, the oxygen in the case in question, makes its appearance at one wire, and the other, the hydrogen, makes its appearance at the other wire. The same holds good with bodies of a more complex character in solution in water. The compound selected by Mr. Bain is cyanide of potassium. With a solution of this, he saturates a long ribbon of paper, similar to that employed in Morse's telegraph. He causes the paper n (fig. 278) to pass over a drum of brass p, between the metal of s and an iron point or stylus r. The electric current enters the apparatus by the point r, passes through the solution of cyanide of potassium, with which the paper n is saturated, and out by the spring r', which is in metallic contact with the drum p. Decomposition takes place, and the well-known cyanide of iron (Prussian blue) is formed at the point of contact of the iron stylus r with the paper, the iron of the compound being supplied by the stylus itself. The paper is carried on by ordinary mechanism; and a dot and dash alphabet is formed, according to the duration of contacts at the sending station. There is a single wire and a double wire code; and the signals appear as deep blue marks upon the paper. Supplies of paper saturated with the solution are kept in reserve. This is unquestionably a telegraph of extreme simplicity; it has been employed with much success.

Mr. Whitehouse prepared for the Atlantic Telegraph a system in which motion and chemical action each play their part. The secondary currents that he employed were not able to produce the chemical decomposition that he requires for his signals. He therefore received them in a very sensitive relay, either an electro-magnet or a multiplier. The relay was a contact-maker, and connected the necessary number of local batteries with the print-
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ing apparatus, which consists of a ribbon of paper, saturated with a chemical solution, and passing between a drum and a steel point.

We should exceed our limits, were we to attempt the description of some of the many other forms that have been proposed. The above are good illustrations of the leading principles, and are all in successful use. Some telegraphs will print in ordinary characters; this result is only attained by much complexity; and its value is more than questionable, it being as easy to learn a new code as a new alphabet; and telegraph clerks read their signals as readily as they read ordinary writing or printing, and they acquire their knowledge in a very short time. Hence, probably, it is that telegraphs to print in ordinary characters are but little known in real practice; nevertheless, some very promising instruments of the class have been produced, by House, and especially one more recently by Hughes, both of the United States. The following table has been drawn out as an illustration of the codes of some of the chief instruments that have been the subject of this article. It shows the number and nature of the signals (deflections, dots, dashes) for producing the name of the great discoverer of electro-magnetism, which is the foundation of electro-telegraphy. The figures on the right are the number of marks or signs in printing, and in each kind of telegraph.

| 2. Double | |
| 3. Single | Henley |
| 4. Double | |
| 5. Morse | |
| 6. Single | Bain |
| 7. Double | |

The Rheo-electro-static system of telegraphy was first described by M. Rotto, in 1848. It is applicable to some but not to all forms of telegraph. It has been applied on the South-Eastern Railway to the signal-bells, (fig. 268,) for the purpose of reducing the amount of battery power required under other circumstances to be maintained. The wire, by which a pair of bells are connected, is in its normal state in permanent connection with the similar pole, say the positive, of batteries of equal power at the respective stations, so that two currents of equal power are opposed to and balanced against each other. Under these circumstances, the wire is in a null, or rheo-electro-static state; neither current circulates. If the connection of one of the batteries is reversed, so that its negative pole is presented to the wire, then the currents of both batteries are in the same direction, and they circulate as one current, equal in value to the combined force of the two batteries. The application is obvious; that, whereas, under the ordinary system, a whole battery, of force sufficient to traverse the distance and do effective work, must be at each station, under this system only half such battery is necessary at each station, for producing the same effective work. Also, if a little more battery power is placed at each station than is necessary for the actual work required, signals of higher power are obtained under common circumstances; and also the equilibrium of the two opposed currents may be disturbed at any place between the two stations, and signals may be made by merely making a connection between the line wire and the earth; because the negative pole at each station is fitted up in permanent connection with the earth; and, as the positive poles are in like connection with the line wire, each battery current is made to circulate through its own signal-bell every time the earth and line wire are placed in connection. By this means the guard of a train can make signals of distress to the nearest station without the aid of portable apparatus. Considerable care is required to obtain good communication with the earth on the open railway for making distress signals, or otherwise the discharge is imperfect, and no signal is made. Fish-jointed rails are very valuable for this purpose; in their absence, especially at embankments, metal must be buried for the purpose at intervals in the moist earth, and a wire attached for use. Contact springs on the telegraph poles are proposed.
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Telegraph wires are suspended to poles by insulators of earthenware, glass, or porcelain; the material and shape varying according to the experience of the engineer and the length of line to be insulated. In very short lengths, the battery power required for overcoming the resistance is not great; it will therefore not overcome the resistance of an insulator of moderate quality, and escape to the pole and thence to the earth; but the battery power required to overcome the resistance of very long lengths of wire is equally able to overcome the resistances presented by inferior insulators, and to escape in considerable quantities at every pole; so that the force which reaches the far station would not be equal to its work. It is for these long lines that the greatest ingenuity has been expended in constructing insulators. Fine porcelain is most in favor, from its presenting a very smooth surface, and being less hygrometric than glass; and it is distorted into most mysterious-looking shapes in order to present as great a distance, and one as much sheltered as possible, between the part with which the line wire is in contact, and the part that is in contact with the pole.

For subterranean and submarine wires still greater care is necessary, because they are in the very bosom of the earth or sea, to which the current will escape, when and where it can, in order to complete the discharge. Fig. 279 represents the cable that has been lying in the British Channel between Dover and Calais, since September, 1851. It contains four No. 16 copper wires; each wire is doubly covered with gutta percha. The four wires are then twisted into a rope, and the rope is thickly covered, first with hempen yarn, tarred, and finally with a jacket of ten No. 1 iron wires. The cable is shown in perspective and in section. Fig. 280 shows the perspective and section of the Irish, a single-wire cable. It consists of a single central conductor, of one No. 10 copper wire, doubly covered with gutta percha, then with hempen yarn as before; and finally with a protecting jacket of ten No. 8 iron wires. The Calais cable weighs 7 tons per mile; the Irish, 2 tons per mile. The Atlantic Telegraph cable, of which nearly 3,000 miles were prepared, is in section, just the size of a silver threepenny piece. It is a single-wire cable; the wire was a strand of seven No. 22 copper wires, trebly covered with gutta percha, then with yarn, and protected with eighteen strands of seven wires each, of No. 22 iron wire. It weighs 19 cwt. to the mile. This cable is lost. The iron jacket is in disrepute now for deep-sea cables. Hemp is preferred.

Telegraph signals pass with far less rapidity through buried and through submarine wires, than along the ancient aerial wires. The slow travellings mentioned above, were through wires of this kind. We must refer to treatises on Electricity for full details of the conditions presented by a telegraph cable. In practice it is found, that on first sending a signal into a submerged wire, the electricity is delayed on its road, in order to produce a certain electrical condition upon the surface of the gutta percha that is in immediate contact with the conducting wire. Nor is this all; before a second distinctive signal can be sent, it is necessary that the condition produced by the first signal shall be destroyed; and this is an operation requiring even more time than was consumed in the mere act of producing it. These two classes of retardation, especially the latter, were largely manifested in the Atlantic cable, and have called forth all the ingenuity of electricians, in order to mitigate or to modify them.—C. Y. W.
EMBOSSING WOOD. A process which may be regarded either as carving or embossing wood, is that patented by Messrs. A. S. Braithwaite & Co.

Oak, mahogany, rosewood, horse-chestnut, or other wood, is steeped in water for about two hours; and the cast-iron mould containing the device is heated to redness, or sometimes to a white heat, and applied against the wood, either by a handle, as a branding-iron, by a lever press, or by a screw press, according to circumstances; the moulds are made by the iron-founder from plaster casts of the original models or carvings.

Had not the wood been saturated with water, it would be ignited, but until the moisture is evaporated, it is only charred; it gives off volumes of smoke, but no flame. After a short time the iron is returned to the furnace to be reheated, the blackened wood is well rubbed with a hard brush to remove the charcoal powder, which being a bad conductor of heat, saves the wood from material discoloration; and before the reapplication of the heated iron, the wood is again soaked in water, but for a shorter time, as it now absorbs moisture with more facility.

The rotation of burning, brushing, and wetting, is repeated ten or twenty times, or upwards, until in fact the wood fills every cavity in the mould, the process being materially influenced by the character and condition of the wood itself, and the degrees to which heat and moisture are applied. The water so far checks the destruction of the wood, or even its change of any kind, that the burned surface, simply cleaned by brushing, is often employed, as it may be left either of a very pale or deep brown, according to the tone of color required, so as to match old carvings of any age; or a very little scraping removes the discolored surface. Perforated carvings are burned upon thick blocks of wood, and cut off with the circular saw.

EMERALD. Fine emeralds are found in a vein of dolomite, which traverses the hornblende slate at Muzo, north of Santa Fé de Bogota. A perfect hexagonal crystal from this locality, two inches long, is in the cabinet of the Duke of Devonshire; it measures across its three diameters 3 3/8 in., 2 1/4 in., 1 3/4 in., and weighs 8 oz. 18 dwts.—owing to flaws, it is but partially fit for jewellery. A more splendid specimen, though somewhat smaller, weighing but 6 oz., is in the possession of Mr. Hope; it cost £500. Emeralds of less beauty, but much larger, occur in Siberia. One specimen in the royal collection measures 14 1/2 inches long and 1 1/2 broad, and weighs 16 1/2 lbs. troy; another is 7 inches long and 4 inches broad, and weighs 6 lbs. troy.—Done.

The emerald is generally believed to derive its color from the presence of a minute quantity of oxide of chrome, the beryl from oxide of iron.

This mineral has been recently examined with great care by M. Lewy, from whose communication to the Academy of Sciences we abstract the following:—

"M. Lewy visited a mine called Muzo, in New Granada, Mexico, and obtained some fine specimens of emeralds, and of the rocks in which those precious stones are found. He observed that the largest and finest emeralds could be reduced to powder by a slight squeezing or rubbing between the fingers when first obtained, but that they acquired hardness after a certain time and repose. It has been commonly stated that the coloring matter of the emerald is chrome, but M. Lewy attributes it to an organic coloring matter, analogous to chlorophyle. He states that the emerald exposed to heat loses all color; whereas minerals colored by chrome do not lose their green color by ignition.

The green color of the emerald is darkest in those specimens which furnish to analysis most organic matter: it is completely destroyed by heat, becoming white and opaque.

ENAMELS. The following was the process adopted by Henry Bone, R. A., and his son, the late Henry Pierce Bone, who have produced the largest enamels ever painted; and beyond the time and consequent expense there appears no practical limit to the size of enamel paintings.

Preparing the Plate.—For small plates, (up to two inches long,) pure gold is the best material. Silver (quite pure) is also used, but is apt to get a disagreeable yellow color at the edges by repeated firings. For larger sizes, copper is used. The copper should be annealed until quite free from spring, and then cleaned with dilute sulphuric acid, (one part acid, four water,) and shaped in a wooden mould, afterwards used in making the plate so as to produce a convex surface varying according to the size of the plate, taking care that the shaping does not reproduce the spring in the copper, in which case the process must be repeated. If the plate is not raised in the centre, in the course of repeated firings the corners will rise irregularly, producing undulations over the plate, perfect flatness being next to impossible for large pictures. The copper is then laid face downwards on the convex wooden mould used for shaping, and enameled ground fine with water is spread over it with
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During a small bone spoon; when covered, a fine cloth doubled is pressed gently on it to absorb the water, and then it is smoothed with a steel spatula. This forms the back of the plate, and when fired this part is finished. The copper is now reversed on a convex board the exact counterpart of the other, and covered with white enamel ground fine in the same way as above. The plate is now ready for firing, and after it has been fired and cooled, the surface must be ground smooth with a flat piece of flint or other hard substance, with silver sand and water. It must next be covered with a softer and more transparent kind of enamel called flux, ground and spread on in the same way as the first enamel, but this time only on the face of the plate. This is fired as before, and when cool the surface must be again ground smooth, and when glazed in the furnace the plate is finished. For the first coat a white solid enamel is used to prevent the green color from the oxidized copper showing through; the second coat is a softer enamel, to enable the colors used to melt with less heat.

Firing.—The plate is placed on a planche of firestone, or well-baked Stourbridge clay, supported on a bed of whiting, thoroughly dried in the furnace, the exact shape of the plate as originally made, which must be used in all subsequent firings. After the whiting is formed in the shape of the plate, it should be notched with a flat knife diagonally across, as in the accompanying diagram. The use of this is to produce an effect of diagonal bracing while the plate cools, and experience has shown that it tends considerably to keep the plate in its original shape. When the plate is small, (up to three inches in length,) it may be annealed for passing into the hot muffle as follows:—The planche bearing the plate may be placed on another planche heated in the muffle and placed in the front of the muffle for a few minutes, until the steam of the plate or the oil of the picture shall have evaporated; it may then be put in the mouth of the muffle and gradually inserted to the hottest part. After firing, it should be placed on another hot planche and allowed to cool gradually. Large pictures require a different arrangement of the furnace. Over the muffle there should be a fixed iron annealing-box, with an iron shelf at the door. The bottom should be of cast iron about one inch thick. This should be so arranged that when the muffle attains a white heat, the bottom of the annealing-box should be of a brightish red at the back, and a dull blood-red in front. Large pictures should be placed on the bottom of the box before the furnace is lit, and the larger the size of the picture, the shorter should the furnace be brought to its full heat, so as to allow five or six hours for the largest size, and two or three for smaller plates. When fired, the picture should be returned to the shelf of the annealing-box, and left there till quite cold, for which purpose large plates require at least twelve hours. The colors used are mostly the same as those prepared for jewellers and glass-painters.

ENCAUSTIC PAINTING. A mode of painting with heated or burnt wax, which was practised by the ancients. The wax, when melted, was mixed with as much color, finely powdered, as it could imbibe, and then the mass was spread on the wall with a hot spatula. When it became cold the designer cut the lines with a cold pointed tool, and other colors were applied and melted into the former. Many modifications of the process have been employed. Amongst the moderns, the term has been improperly given to some cements, which have nothing of an encaustic character about them.

In ENGRAVING, engraving on metal plates may be classed under the following heads: Etching, line, mezzotinto, chalk, stipple, and aquatint. Before describing the processes of working these respective kinds, a notice of the instruments used by the engraver is necessary. These, with some modifications, are employed in all the styles.

The etching-point, or needle, is a stout piece of steel wire inserted into a handle; two or three, varying in thickness, are requisite, and they should be frequently and carefully sharpened. This is best done by turning the needle round in the fingers while rubbing it on a hone, and afterwards on a leather strop prepared with putty powder, or on an ordinary razor-strop, to take off any roughness, and to make it perfectly round.

The dry-point is a similar instrument, used for delicate lines: it must be sharpened on the hone till a fine conical point is obtained.

The groover, or burin, is the principal instrument employed in engraving; several are required, differing from each other in form, from the extreme lozenge shape to the square: the former being used for cutting fine lines, the latter for broad: the graver fits into a handle about five inches and a half long, and it should be well tempered before using—an operation requiring great care. The angle at the meeting of the two lower sides is called the belly, and the breadth of the end, the face. To sharpen the former, lay one of the flat sides of the graver on the oilstone, keeping the right arm tolerably close to the side, and rub it firmly; next rub the other in the same way: the face is sharpened by holding it firmly in the hand, with the belly upwards, in a slanting direction; rub the end rather
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gently on the stone, at an angle of about forty-five degrees, taking care to carry it evenly along until it acquires a very sharp point: this being done, hold the graver a little more upright to square the point, which a very few rubbings will effect. The graver for line work must be slightly turned up, to enable the engraver to run it along the plate; otherwise the first indentation he makes on the metal, would cause his instrument to become fixed: the graver for stipple should be slightly turned down, to make dots only.

The scraper, which should have three fluted sides, is used for taking off the burr left by the action of the needles on the metal.

The burnisher is employed to soften lines that have been bitten in, or engraved too dark, and to polish the plate, or get rid of any scratches it may accidentally have received.

The döbler used to lay the etching-ground evenly, is made by enclosing a small quantity of fine cotton wool very tightly in a piece of silk, the threads of which should be, as much as possible, of uniform thickness.

There are a few other materials which an engraver should have at hand, but they are not of sufficient importance to be mentioned here; we may, however, point out what is technically called a bridge, which is nothing more than a thin board for the hand to rest on; it should be smoothly planed, and of a length and breadth in proportion to the size of the plate; at each end a small piece of wood should be fastened to raise it above the plate when covered with wax. A blind, made of tissue paper stretched upon a frame, ought to be placed between the plate and the light, to enable the engraver to see his work on the metal with greater facility and clearness.

In describing the processes of engraving the various styles enumerated above, little more than a general outline of each method can be given, yet sufficient, it may be presumed, to show the nature of the operation: to narrate all the details that might be included in the subject would supply matter enough for a small volume.

Etching may be classed under two heads: that which is made the initiatory process in line engraving, and that which is known as painter's etching. The latter was practised to some extent by very many of the old painters, particularly those of the Dutch school; and it has also recently come into fashion with many of the artists of our own day, but more for amusement, however, than for any other purpose; in both cases the method of proceeding is alike. Etching is the result of a chemical process resulting in corrosion of the metal on which the design has been laid down, or transferred, in the following manner:—The plate must first be covered with a substance already spoken of as etching-ground, which may be purchased of most of the principal artists' colomnen, but many engravers make their own: the annexed receipt has been handed to us by Mr. C. W. Sharpe, who has engraved some of the largest steel-plates published recently, as that which he always uses:

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Black pitch</td>
<td>1</td>
</tr>
<tr>
<td>White wax</td>
<td>1</td>
</tr>
<tr>
<td>Burgundy pitch</td>
<td>1</td>
</tr>
<tr>
<td>Asphaltum</td>
<td>1</td>
</tr>
<tr>
<td>Gum mastic</td>
<td>1</td>
</tr>
</tbody>
</table>

Melt the first three ingredients over a slow fire in a piipkin, then add the other two, finely powdered, stirring the whole together all the time; when well mixed, pour it into warm water, and make it up, while warm, into balls; if too soft, a little less wax should be used. Care must be taken not to let the mixture burn during the process of making.

The etching-ground resists the action of the aqua fortis. It should be tied up in a piece of strong silk, and applied thus, which is called laying the ground:—Take the plate firmly in a small hand-vise; hold it, with the polished face upwards, over a charcoal fire that it may not get smocked, till it is well, but not too much, heated; rub the etching-ground, in the silk, over the plate till it is evenly colored; the wax, melting with the heat, oozes through the silk. To effect a more equal distribution of the ground, take the dobler and dab the plate gently all over, till it appears of a uniform color; continue the dabbing till the plate begins to cool, but not longer. The ground is then blackened by being held over the smoke of a candle, or two or three tied together,—wax is far preferable to tallow; keep the plate in motion, so that every part be made equally dark, and also to avoid injury, by burning, to the composition; when cold, the plate is ready to receive the design. To transfer this, a very correct outline of the subject is made with a black-lead pencil on a piece of thin hard paper; fasten the tracing, or drawing, at the top edge, with its face downwards, on to the etching-ground, with a piece of banking-wax, described hereafter, and by passing it through a printing-press—as such is used by plate printers, to whom it should be taken—the drawing is transferred to the ground. The bridge being laid over the plate, the process of etching may now be commenced; the points, or needles, which are used to complete the design, remove the ground from the metal wherever they pass, and expose the latter to the action of the acid during the process of what is termed biting in. The needles with the most tapering points should be used for the skies and distances, and expose the latter to the action of the acid during the process of what is termed biting in. The needles with the most tapering points should be used for the skies and distances, and expose the latter to the action of the acid during the process of what is termed biting in. The needles with the most tapering points should be used for the skies and distances, and expose the latter to the action of the acid during the process of what is termed biting in. The needles with the most tapering points should be used for the skies and distances, and expose the latter to the action of the acid during the process of what is termed biting in.
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that has been made may be remedied by covering the part evenly with the etching-ground modified by spirits of turpentine, using a camel's-hair pencil for the purpose; and, when dry, the lines may be refetched through it.

The next operation is that of biting in, performed thus:—A wall or border of banking-wax is put round the edge of the plate: this wax, called sometimes bordering-wax, is made by melting over a slow fire, in a glazed pot, two parts of Burgundy pitch and one of bees-wax, to which is added, when melted, a gift of sweet oil; when cold it is quite hard, but by immersion in warm water it becomes soft and ductile, and must be applied in this state; it will adhere to the metal by being firmly pressed down with the hand; the object in thus banking up the plate is to prevent the escape of the acid which is to be applied; but a spout or gutter must be left at one corner to pour off the liquid when necessary. Mr. Fielding—
to whose work on the art of engraving we are indebted for some of the practical hints here adduced, availing ourselves, however, of the improvements introduced into modern practice—recommends the following mixture as the best:—“Procure some strong nitrous acid, and then mix, in a wide-mouthed bottle, one part of the acid with five parts of water, adding to it a small quantity of sal ammoniac, in the proportion of the size of a hazel-nut to one pint of acid, when mixed for biting. The advantage of using the sal ammoniac is, that it has the peculiar property of causing the acid to be more directly downwards, and less laterally, by which means lines laid very closely together are less liable to run into each other, nor does the ground so readily break up.” When the mixture is cool—for the acid becomes warm when first mixed with water—pour it on the plate, and let it continue there till the more delicate lines are presumed to be corroded to a sufficient depth; this will probably be in about a quarter of an hour; sweep off the bubbles as they appear on the plate, with a camel's-hair pencil, or a feather; then pour off the acid through the gutter at the corner, with warm water, and leave it to dry. Next, cover those parts which are sufficiently bitten in with Brunswick black, applying it with a camel's-hair pencil, and leave it to dry; again put on the acid, and let it remain twenty minutes or half an hour, to give the next degree of depth required; and repeat this process of stopping out and biting in, until the requisite depths are all attained: three bitings are generally enough for a painter's etching. The work is now complete, unless the graver is to be used upon it, and the banking-wax may be removed, by slightly warming the margin of the plate, and finally, wash the latter with a soft rag dipped in spirits of turpentine, and rubbing it with olive oil. If, when the plate is cleaned, the engraver finds that the acid has acted as he wishes, he has secured what is technically termed “a good bite.”

Steel plates require another method of biting in, on account of their extreme hardness, and liability to rust; the mode just described is applicable only to copper, the metal generally used by painters for their etchings. For steel plates mix together

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<tbody>
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<td>Pyroligneous acid</td>
</tr>
<tr>
<td>Nitric acid</td>
</tr>
<tr>
<td>Water</td>
</tr>
</tbody>
</table>

This mixture should not be allowed to remain on above a minute; let it be washed off at once, and never use the same water twice; the plate must be set up on its edge, and dried as quickly as possible to avoid rust: the acid may be strengthened where a stronger tint is required.

Rebiting, a process frequently adopted to increase the depth of that where it is required, or to repair any portion of a plate that has been worn by printing or accidentally injured, is thus performed. The plate must be thoroughly cleaned, all traces of grease removed, by washing it with spirits of turpentine and potash, and polished with whitening; it is then, when warmed over a charcoal fire or with lighted paper, ready for receiving the ground; this is laid by using a dabber charged with etching-ground, and carefully dabbing the surface; by this means the surface of the plate only is covered, and the lines already engraved are left clear; any part of the plate that may not be necessary to rebite, must be stopped out with Brunswick black, and then the acid may be pored over the whole, as in the first process.

Etching on soft ground is a style of engraving formerly much practised in imitation of chalk or pencil drawings; since the introduction of lithography, however, it has been entirely abandoned. The soft ground is made by adding one part of hog's lard to three parts of common or hard etching-ground, unless the weather be very warm, when a smaller quantity of lard will suffice; it should be laid on and smoked in the manner already described. Mr. Fielding gives the following method for working on it:—“Draw the outline of your subject faintly on a piece of smooth thin writing paper, which must be at least an inch larger every way than the plate; then damp it, and spread it cautiously on the ground, and, turning the edges over, paste down to the back of the plate; in a few hours the paper will be dry, and stretched quite smooth. Replacing your hand on the bridge, take an H or HB pencil, and draw your subject on the paper exactly as you wish it to be, pressing strongly for the darker touches, and more lightly for the delicate parts, and, accordingly as you find

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the ground more or less soft, which depends on the heat of the weather or the room you
work in, use a softer or harder pencil, remembering always that the softer the ground, the
softer the pencil" (should be). "When the drawing is finished, lift up the paper carefully
from the plate, and wherever you have touched with the pencil, the ground will stick to the
paper, leaving the copper more or less exposed. A wall is then put round the margin, the
plate is laid, and if too feeble, rebid in the same way as a common etching, using hard etch-
ing-ground for the rebate."

"Line engraving unquestionably occupies the highest place in the category of the art;
and, taking it as a whole, it is the most suitable for representing the various objects
that constitute a picture. The soft, pulpy, and luminous character of flesh; the rigid, hard,
and metallic character of armor; the graceful folds and undulations of draperies, the twittering,
unsteady, and luxuriant foliage of trees, with the bright yet deep-toned color of skies, have
by this mode, when practised by the best engravers, been more successfully rendered than
by any other. The process of line engraving is, first, to etch the plate in the manner
already described, and afterward to finish it with the graver and dry-point. An engraver's
etching differs from a painter's etching in that every part of the work has an unfinished ap-
pearance, though many engravers, especially of landscapes, carry their etchings so far as to
make them very effective: engravers of historical and other figure subjects, generally, do
little more than etch the outlines, and the broad shadowed masses, or colors, of the draper-
ies; the flesh being entirely worked in with the burin, or graver: no definite rules can be
laid down as to the extent to which the etching should be advanced ere the work of the tool
commences, as scarcely two engravers adopt the same plan precisely; much must always
depend on the nature of the subject. Neither would it be possible to point out in what par-
ticular way the graver should be used in the representation of any particular object—this
can only be learned in the studio of the master, or by studying the works of the best en-
gravers: as a rule it may be simply stated, that in making the incision, or line, the graver
is pushed forward in the direction required, and should be held by the handle, at an angle
very slightly inclined to the place of the steel or copper plate: the action of the graver is to
cut the metal clean out.
Within the last few years an instrument, called a ruling machine, has been brought into
use for laying in flat tints in skies, buildings, and objects requiring straight, or slightly
curved lines; considerable time is saved to the artist by its use, and more even tints are
produced than the most skilful handwork, generally, is able to effect; but to counterbalance
these advantages, freedom is frequently sacrificed, and in printing a large number of impres-
sions, the machine work, unless very skilfully ruled in, is apt to wear, or to become clogged
with ink, sooner than that which is graved.

Mezzotinto engraving is generally supposed to owe its origin to Colonel Ludwig von
Siegen, an officer in the service of the Landgrave of Hesse; there is extant a portrait by
him, in this style, of Amelia, princess of Hesse, dated 1643. Von Siegen is said to have
communicated his invention to Prince Rupert, to whom many writers have assigned the
credit of originating it. There are several plates executed by the Prince still in existence.
It differs from every other style of engraving, both in execution and in the appearance of
the impression which the plate yields: a mezzotint engraving resembles a drawing done in
washes of color, by means of a camel's-hair pencil, rather than a work executed with any
sharp-pointed instrument: but a pure mezzotint engraving is rarely produced in the present
day, even for portraits: the advantages derived from combining line and stipple, of which
we shall speak presently, with it, to express the different kinds of texture in objects, have
been rendered so obvious as almost to make them necessary: this combination is termed
the mixed style. The distinguishing excellencies of mezzotint are the rich depth of its
shadows, an exquisite softness, and the harmonious blending of light and shade: on the
other hand, its great defect is the extreme coldness of the high lights, especially where they
occur in broad masses.

The instruments used for this kind of work are, burnishers, scrapers, shading tools, rou-
lettes, and a cradle, or rocking tool. The burnisher and scraper differ in form from those
already described: the roulette is used to darken any part which may have been scraped
away too much; it ought to be of different sizes: the cradle is of the same form as the
shading tool, and is used for the purpose of laying grounds.

The operation of engraving in mezzotint is precisely the opposite of that adopted in all
other styles: the processes in the latter are from light to dark; in the former from dark to
light, and is thus effected: A plate of steel or copper is indented all over its face by the
cradle, an instrument which somewhat resembles a chisel with a toothed or serrated edge,
by which a burr is raised on every part in such quantities that if filled in with ink, and
printed, the impression would exhibit a uniform mass of deep black: this operation is called
laying the ground; it is performed by rocking the cradle to and fro, and the directions, or
shape of the burrs, the engravers call them, are determined by a plan, or scale, that enables the
engraver to pass over the plate in almost any number of directions without repeating any
one of them. When an outline of the subject has been first etched in the ordinary way be-
fore the ground is laid, the engraver proceeds to scrape away, and then burnish the highest lights, after which the next lightest parts are similarly treated, and the process is repeated after this manner till the work is finished; the deepest shades are produced from the ground that is left untouched. There is, however, no style of engraving for the execution of which it is so difficult to lay down any definite rules, for almost every engraver has his own method of working.

*Chalk* or *stipple* engraving, for the terms are synonymous, is extremely simple. The plate has first to be covered with the etching-ground, and the subject transferred to it in the ordinary way: the outline is then laid in by means of small dots made with the stipple graver; all the darker parts are afterwards etched in dots larger and laid closer together. The work is then bitten in with the acid; and the ground being taken off, the stipple graver must again be taken up to complete the operation; the light parts and the dark are respectively produced by small and large dots laid in more or less closely together. Stipple is well adapted for, and is often used in, the representation of flesh, when all the other parts of the subject are executed in line; hence it is very frequently employed in portraiture, and in engravings from sculpture. *Chalk engraving* is simply the imitation of drawings in chalk, and is executed like stipple, only that the dots are made with less regularity, and less uniformity of size; in the present day, the two terms are generally considered as expressing the same kind of work.

*Aquatint* engraving, which represents a drawing in Indian-ink or bistre even more than does mezzotint, has been almost entirely superseded by lithography, and still more recently by chromo-lithography; and there seems little probability that it will ever come into fashion again. This being the case, and as any detailed description of the mode of working would, to be of any service, occupy a very considerable space, it will, doubtless, be deemed sufficient to give only a brief outline of its character and of the mode of operation; this we abbreviate from the notice of Mr. Fielding, formerly one of our most able engravers in aquatint. The process consists in pouring over a highly-polished copper plate a liquid composed of resinous gum dissolved in spirits of wine, which latter, evaporating, leaves the resin spread all over the plate in minute grains that resist the action of the aqua fortis, which, however, corrodes the bare surface of the copper that is left between them; this granulated surface is called a *ground*. The ground having been obtained, the margin of the plate should be varnished over, or stopped out, and when dry, the subject to be aquatinted must be transferred to the plate, either by tracing or drawing with a soft black-lead pencil, which may be used on the ground with nearly the same facility as paper; if the former method be adopted, the tracing must be carefully fastened down to the copper by bits of wax along the upper edge. A piece of thin paper, covered on one side with lamp-black and sweet oil, is placed between the tracing and the ground, with the colored side downwards, and every line of the subject must be passed over with the tracing-point, using a moderate pressure. The tracing being finished and the paper removed, a wall of prepared wax, about three-quarters of an inch high, must be put round the plate, with a large spout at one corner, to allow of the acid running off.

The plate is now ready for use; and the completion of the design is commenced by stopping out the highest lights on the edges of clouds, water, &c., with a mixture of oxide of iron, burnt, and nitrous acid, diluting it with spirits of turpentine, till of a proper consistence to work freely. Next pour on the acid, composed of one part of strong nitrous acid and five parts of water; let it remain, according to its strength, from half a minute to a minute, then let it run off, wash the plate two or three times with clean water, and dry it carefully with a linen cloth. This process of stopping out and refining is continued till the work is complete; each time the aqua fortis is applied a fresh tint is produced, and as each part successively becomes dark enough it is stopped out; in this manner a plate is often finished with one ground bitten in ten or twelve times. We would recommend those who may desire to become thoroughly acquainted with this very interesting yet difficult mode of engraving to consult Fielding's *Art of Engraving*.

A few remarks explanatory of the method of printing steel or copper plates seem to be inseparable from the subject. The press used for the purpose consists of two cylinders or rollers of wood, supported in a strong wooden frame, and movablc at their axes. One of these rollers is placed just above, and the other immediately below, the plane or table upon which the plate to be printed is laid. The upper roller is turned round by means of cogged wheels fixed to its axis. The plate being inked by a printer's inking-roller, an operation requiring great care, the paper which is intended to receive the impression is placed upon it, and covered with two or three folds of soft wooden stuff like blanketing. These are moved along the table to the spot where the two rollers meet; and the upper one being turned by the handle fixed to the fly-wheel, the plate passes through it, conveying the impression as it moves; the print is then taken off the plate, which has to undergo the same process of taking for the next and every succeeding impression. The *proofs* of an engraved plate are always taken by the most skilful workmen in a printing establishment; in the principal houses there are generally employed from two to six men, according to the
amount of business transacted, whose duty it is to print proof impressions only; they are called proofs. A careful, steady workman is not able to print more than from 180 to 200 good ordinary impressions from a plate, the subject of which occupies about seven inches by ten inches, even in what is considered a long day's work, that is, about fourteen hours; the proof, from the extreme care required in inking the plate, and from the extra time occupied in wiping it, and preparing the India-paper, will do from thirty to forty, according as the subject of the plate is light or heavy. This difference in the cost of production, taking also into account that the proofs are worked off before the plate has become worn, even in the least degree, and that very few proofs, compared with the ordinary prints, are generally struck off, is the reason why they are sold at a price so much greater than the latter.

Notwithstanding the vast multiplication of engravings within the last few years, it is generally admitted, by those best acquainted with the present state of the art, that it is not in a healthy condition. The highest class of pictorial subjects—history, and the highest style of engraving—line, have given place to subjects of less exalted character, and to a mixed style of work, which, however effective for its especial purpose, is not pure art. The pictures by Sir R. Landseer have gained for engravings of such subjects a popularity that has driven almost every thing else out of the field, and have created a taste in the public which is scarcely a matter of national congratulation. We have engravers in the country capable of executing works equal to whatever has been produced elsewhere at any time, but their talents are not called into requisition in such a way as to exhibit the art of engraving in its highest qualities. Publishers are not willing to risk their capital on works which the public cannot appreciate, and hence their windows are filled with prints, the subjects of which, however pleasing and popular, are not of a kind to elevate the taste; while the conditions under which engravers generally are compelled to work, offer but little inducement for the exercise of the powers at their command. Engraving on copper is in the present day but rarely attempted; formerly nothing else was thought of; now the demand for engraving is so great that copper, even aided by the electrotyping, is insufficient to meet its requirements. In consequence of the comparatively small number of impressions which it yields, a copper-plate will seldom produce more than 500 or 600 good prints; we have known a steel, with occasionally retouching, produce more than 50,000, when well engraved, and carefully printed; very much depends on the printer, both with regard to the excellence of the impression and the durability of the plate. The public demand is for prints both large and cheap, and to obtain this result, the engraver is too often obliged to sacrifice those qualities of his art which under other circumstances his work would exhibit. Such is the state of engraving with us now. There are few, even of the best artists we have, who by their utmost efforts can earn an income equal to that of a tradesman in a small but respectable way of business. This is an evil to be deplored, for it assists to deteriorate the art by forcing the engraver to labor hard for a maintenance, instead of placing him in a position that would enable him to exalt the art and his own reputation at the same time.

A process of depositing steel upon an engraved copper-plate has recently been brought over to this country from France. M. Joubert, a French engraver long settled in England, has introduced it here; he has informed us that a copper-plate thus covered may be made to yield almost any number of impressions, for as the steel coating becomes worn it can be entirely taken off, and a new deposit laid on without injury to the engraving, and this may be done several times; M. Joubert has repeated the experiment with the most satisfactory results. He thus describes his process in a communication made to the Society of Arts, and printed in their journal:—

"If the two wires of a galvanic battery be separated partly into a solution of iron, having ammonia for its basis, the wire of the positive pole is immediately acted upon, while that of the negative pole receives a deposit of the metal of the solution—this is the principle of the process which we have named 'acelage.'

"The operation takes place in this way:—by placing at the positive pole a plate or sheet of iron, and immersing it in a proper iron solution, the metal will be dissolved under the action of the battery, and will form a hydrochlorate of iron, which, being combined with the hydrochlorate of ammonia of the solution, will become a bichloride of ammonia and iron; on a copper-plate being placed at the opposite pole and likewise immersed, if the solution be properly saturated, a deposit of iron, bright and perfectly smooth, is thrown upon the copper-plate, from this principle:—

"1st. Water being composed of hydrogen and oxygen:—

"2d. Hydrochloric acid, containing chlorine and hydrogen;—

"3d. Ammonia, containing oxygen, nitrogen, and oxygen:—

"The water is decomposed under the galvanic action, and the oxygen fixes itself on the iron plate, forming an oxide of iron; the acid hydrochloride of the solution, acting upon this oxide, becomes a hydrochloratite of iron, whilst the hydrogen precipitates itself upon the plate of the negative pole, and, unable to combine with it, comes up to the surface of the solution in bubbles."
"My invention has for its object certain means of preparing printing surfaces, whether for intaglio or surface printing, so as to give them the property of yielding a considerably greater number of impressions than they are capable of doing in their ordinary or natural state. And the invention consists in covering the printing surfaces, whether intaglio or relief, and whether of copper or other soft metal, with a very thin and uniform coating of iron, by means of electro-metallurgical processes. And the invention is applicable whether the device to be printed from be produced by engraving by hand, or by machinery, or by chemical means, and whether the surface printed from be the original, or an electrotype surface produced therefrom. I would remark that I am aware that it has been before proposed to coat type and stereotypes with a coating of copper, to enable their surfaces to print a larger number of impressions than they otherwise would do; I therefore lay no claim to the general application of a coating of harder metal on to the surface of a softer one, but my claim to invention is confined to the application of a coating of iron by means of electricity on to copper and other metallic printing surfaces.

In carrying out the invention I prefer to use that modification of Grove's battery known as Bunsen's, and I do so because it is desirable to have what is called an intensity arrangement. The trough I use for containing the solution of iron in which the engraved printing surface is to be immersed in order to be coated, is lined with gutta percha, and it is 45 inches long, 22 inches wide, and 32 inches deep. In proceeding to prepare for work, the trough, whether of the size above mentioned or otherwise, is filled with water in combination with hydrochlorate of ammonia (sal ammoniac) in the proportion of one thousand lbs. by weight of water to one hundred lbs. of hydrochlorate of ammonia. A plate of sheet iron, nearly as long and as deep as the trough, is attached to the positive pole of the battery and immersed in the solution. Another plate of sheet iron, about half the size of the other, is attached to the negative pole of the battery, and immersed in the solution, and when the solution has arrived at the proper condition, which will require several days, the plate of iron attached to the negative pole is removed, and the printing surface to be coated is attached to such pole, and then immersed in the bath till the required coating of iron is obtained thereto. If, on immersing the copper plate in the solution, it be not immediately coated with a bright coating of iron all over, the bath is not in a proper condition, and the copper plate is to be removed and the iron plate attached and returned into the solution. The time occupied in obtaining a proper coating of iron to a printing surface varies from a variety of causes, but a workman after some experience and by careful attention will readily know when to remove the plate from the solution; and it is desirable to state that a copper plate should not be allowed to remain in the bath and attached to the negative pole of the battery after the bright coating of iron begins to show a blackish appearance at the edges. Immediately on taking a copper plate from the bath great care is to be observed in washing off the solution from all parts, and this I believe may be most conveniently done by causing jets of water forcibly to strike against all parts of the surface. The plate is then dried and washed with spirits of turpentine, when it is ready for being printed from in the ordinary manner.

If an engraved copper plate be prepared by this process, instead of a comparatively limited number of impressions being obtained and the plate wearing out gradually, a very large number can be printed off without any sign of wear in the plate, iron coating protecting it effectually; the operation of coating can be repeated as many times as required, so that almost an unlimited number of impressions can be obtained from one plate, and that a copper one.

This process will be found extremely valuable with regard to electrotype plates and also for photo-galvanic plates, since they can be so protected as to acquire the durability of steel, and more so, for a steel plate will require repairing from time to time, these will not, but simply recasting them whenever it is found necessary; by these means one electrotype copper plate has yielded more than 12,000 impressions, and was found quite unimpaired when examined minutely."—J. D.

ENGRAVING ON WOOD. In order to make the whole process of wood engraving clear to the reader, we will describe the production of a wood-cut from the time it leaves the timber-merchant, until it is fit for the hands of the printer. The log of box is cut into transverse slices, ⅔ of an inch in depth, in order that the face of the cut may be on a level with the surface of the printer's type, and receive the same amount of pressure; the block is then allowed to remain some time to dry, and the longer it is allowed to do so the better, as it prevents accidents by warping and splitting, which sometimes happen after the cut is executed if the wood is too green. The slice is ultimately trimmed into a square block, and if the cut be large, it is made in various pieces strongly clamped and screwed together; and this enables engravers to get large cuts done in an incredibly short space of time, by putting the various pieces into different engravers' hands, and then screwing the whole together. The upper surface of the wood is carefully prepared so that no inequalities may appear upon it, and it is then confided to the draughtsman to receive the drawings which covers the surface with a light coat of flake white mixed with weak gum-water, and the
thinner this coat the better for the engraver. The French draughtsmen use an abundance of flake white, but this is liable to make the drawing rub out under the engraver's hands, or deceive him as to the depth of the line he is cutting in the wood. The old drawings of the era of Durer seem to have been carefully drawn with pen and ink on the wood; but the modern drawing being very finely drawn with the pencil or silver point is obliterated easily, and there is no mode of "setting" or securing it. To obviate this danger the wood-engraver covers the block with paper, and tears out a small piece the size of a shilling to work through, occasionally removing the paper to study the general effect; in damp and wintry weather he sometimes wears a shade over the mouth to hinder the breath from settling on the block. It is now his business to produce in relief the whole of the drawing; with a great variety of tools he cuts away the spaces, however minute, between each of the pencil lines; and should there be tints washed on the drawing to represent sky and water, he cuts such parts of the block into a series of close lines, which will, as near as he can judge, print the same gradation of tint. Should he find he has not done so completely, he can reinsert each line with a broader tool, cutting away a small shaving, thus reducing their width and consequently their color. Should he make some fatal error that cannot be otherwise rectified, he can cut out the part in the wood, and wedge a plug of fresh wood in the place, when that part of the block can be reengraved. An error of this sort in a wood-cut is a very troublesome thing; in copper engraving it is scarcely any trouble; a blow with a hammer on the back will obliterate the error on the face, if in the wood, the surface is cut entirely away except where the lines occur, and it is necessary to cut it deep enough not to touch the paper as it is squeezed through the press upon the lines in printing. To aid the general effect of a cut, it is sometimes usual to lower the surface of the block, before the engraving is executed, in such parts as should appear light and delicate; they thus receive a more touch of the paper in the press, the darker parts receiving the whole pressure and coming out with double brilliance. When carefull printing is bestowed on cuts, it is sometimes usual to insure this good effect, by laying thin pieces of card or paper upon the tympan, of the shape needed to secure pressure on dark parts only.

Wood engraving, as a most useful adjunct to the author, must always command a certain amount of patronage. In works like the present, the author is greatly aided by a diagram, which can more clearly explain his meaning than a page of letter-press; and it can be set up and printed with the type, a mode which no other style of art can rival in simplicity and cheapness. The taste for elaborately-executed wood engravings may again decrease, as we find it did for nearly two centuries; but it was never a lost art, and never will be, owing to the practical advantages we speak of, unless it be superseded by some simpler mode of doing the same thing hitherto undiscovered. The number of persons who practise wood engraving in London alone, at present is more than 200, and when we consider the quantity done in the great cities of the continent, and the large amount of book illustration in constant demand, the creative power of one single genius—Thomas Bewick—shines forth in greater vigor than ever.—F. W. F.

ENVELOPES.

The manufacture of envelopes has so largely increased, that the old method of folding them by means of a "bone folding-stick," although a good workman could thus produce 3,000 a day, was not capable of meeting the demand; hence the attention of several was turned to the construction of machines for folding them. Amongst the most successful are the following:—

Envelope folding.—In the envelope-folding machine of Messrs. De la Rue & Co., each piece of paper, previously cut by a fly press into the proper form for making an envelope, (and having the emblematical stamp or wafer, upon it,) is laid by the attendant on a square or rectangular metal frame or box, formed with a short projecting piece at each corner, to serve as guides to the paper, and furnished with a movable bottom, which rests on helical springs. A presser at the end of a curved compound arm (which moves in a vertical plane) then descends, and presses the paper down into the box, the bottom thereof yielding to the pressure; and thereby the four ends or flaps of the piece of paper are caused to fly up; the presser may be said to consist of a rectangular metal frame, the ends of which are attached to the outer part of the curved arm, and the sides thereof to the inner portion of the arm; so that the ends and sides of the presser can move independently of each other. The ends of the presser then rise, leaving the two masses of it still holding down the paper; two little lappet pieces next fold over the two side flaps of the envelope; and immediately a horizontal arm advances, carrying a V-shaped piece charged with adhesive matter or cement, (from a saturated endless band,) and applies the same to the two flaps. A third lappet presses down the third flap of the envelope upon the two cemented flaps, and thereby causes it to adhere thereto; and then a pressing-piece, of the same size as the finished envelope, folds over the last flap and presses the whole flat. The final operation is to remove the envelope, and this is effected by a pair of metal fingers, with india-rubber ends, which descend upon the envelope, and, moving sideways, draw the envelope off the bottom of the box (the pressing piece having moved away and the bottom of the box risen to the level of the platform of the machine) on to a slowly-moving endless band, which gradually carries
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The finished envelopes away. A fresh piece of paper is laid upon the box or frame, and the above operations are repeated. This machine makes at the rate of 5,700 envelopes per hour.

Another machine for the same object, was invented by Mr. A. Remond, of Birmingham, and is that employed by Messrs. Dickinson & Co. The distinguishing feature of this arrangement is the employment of atmospheric pressure to feed in the paper which is to form the envelope, and to deflect the flaps of the envelope into inclined positions, to facilitate the action of a plunger, which descends to complete the folding. The pieces of paper, cut to the proper form, are laid on a platform, which is furnished with a pin at each corner, to enter the notches in the pieces of paper, and retain them in their proper position, and such platform is caused alternately to rise and bring the upper piece of paper in contact with the instrument that feeds the folding part of the machine, and then to descend until a fresh piece is to be removed. The feeding instrument consists of a horizontal hollow arm, with two holes in the under side, and having a reciprocating movement. When it moves over the upper piece of paper on the platform, a partial vacuum is produced within it, by a suitable exhausting apparatus, and the paper is thereby caused to adhere to it at the holes in its under surface by the pressure of the atmosphere. The instrument carries the paper over a rectangular recess or box; and then, the vacuum within it being destroyed, it deposits the paper between four pins, fixed at the angles of the box, and returns for another piece of paper. As the paper lies on the top of the box, the flap which will be undermost in the finished envelope, is pressed by a small bar or presser on to the upper edge of two angular feeders, communicating with a reservoir of cement or adhesive matter, and thereby becomes coated with cement; and at the same time, the outermost or seal flap may be stamped with any required device, by dies, on the other side of the machine. A rectangular frame or plunger now descends and carries the paper down into the box; the plunger rises, leaving the flaps of the envelope upright; streams of air, issuing from a slot in each side of the box, then cause the flaps to incline inwards: and the folding is completed by the plunger again descending; the interior and under surface of such plunger being formed with projecting parts, suitable for causing the several flaps to fold in proper superposition. The bottom of the box (which is hinged) opens, and discharges the envelope down a shoot on to a table below; the feeding instrument then brings forward another piece of paper; and a repetition of the above movements takes place.

EREMACUSIS.—slow combustion. This term has been applied to that constant combination of oxygen with carbon and hydrogen, to form carbolic acid and water, which is unceasingly going on in nature, as in the decay of timber, or the "heating" of hay or grain put together in a moist state. Perfect dryness, and a temperature below freezing, stops this eremacusis, or slow combustion.

ETHER, C₂H₂O. Syn. Sulphuric ether, Oxide of ethyl, Ethylic or Venie ether, &c. &c. By this term is known the very volatile fluid produced by the action on alcohol of substances having a powerful affinity for water.

Preparation on small scale.—A capacious retort with a moderate-sized tubulation is connected with an efficient condensing arrangement. Through the tubulation passes a tube connected with a vessel full of spirit, sp. gr. 0·83. The tube must have a stopcock to regulate the flow. A mixture being made of five parts of alcohol of the density given above, and nine parts of oil of vitriol, it is to be introduced into the retort, and a lamp flame is to be so adjusted as to keep the whole gently boiling. As soon as the ether begins to come over, the stopcock connected with the spirit reservoir is to be turned sufficiently to keep the fluid in the retort at its original level.

Preparation on large scale.—The apparatus is to be arranged on the same principle, but, for fear of fracture, may be constructed of cast iron, lined with sheet lead in the part containing the mixture. The chief disadvantage of this arrangement is its opacity, whereby it becomes impossible to see the contents of the retort, and therefore not so easy to keep the liquid at its original level. In this case the quantity distilling over must be noted, and the flow of spirit into the retort regulated accordingly. The most convenient mode of proceeding is to have a large stone bottle with a tubulation at the side near the bottom (like a water-filter) to hold the spirit. A tube passes from the bottle to the retort. It has at the end, near the retort or still, a bend downwards leading into the tubulation. If a glass still be used it must for safety be placed in a sand bath. The distillate obtained, either on the large or small scale, is never pure ether, but contains sulphurous and acetic acids, besides water and alcohol. To remove these, the distillate is introduced, along with a little cream of lime, into a large separating-globe, such as that mentioned under Bromine. The whole is to be well agitated, and the lime solution then run off by means of the stopcock. The purified ether still contains alcohol and water, to remove which it should be rectified in a water bath perfect, and will then constitute the ether of commerce. If the second distillation be pushed too far the ether will, if evaporated on the hand, leave an unpleasant after smell, characteristic of impure ether. If wished exceedingly pure, it must be shaken up in
EXOSMOSIS AND ENDOMOSIS.

the separating globe, with pure water. This will dissolve the alcohol and leave the ether, contaminated only by a little water, which may be removed by distillation at a very low temperature on a hot water bath.

Pure ether is a colorless mobile liquid, sp. gr. 0.71. It boils at 95° F. The density of its vapor is 2.56 (calculated). Guy Lussac found it 2.586.

The word ether, like that of alcohol, aldehyde, etc., is now used as a generic term to express a body derived from an alcohol by the elimination of water. Many chemists write the formula C\(_6\)H\(_5\)O, and call it oxide of ethyle in the same manner as they regard alcohol as the hydrated oxide of the same radical. But there is no just reason for departing from the law we have laid down with reference to the formula of organic compounds. (See Chemical Formula.) We shall therefore write ether C\(_2\)H\(_4\)O\(_2\). This view has many advantages. We regard, with Gerhardt and Williamson, ether and alcohol as derived from the type water. Alcohol is two atoms of water in which one equivalent of hydrogen is replaced by ethyle; ether is two atoms of water in which both atoms of hydrogen are replaced by that radical. But there is a large class of compound ethers procurable by a variety of processes. These ethers were long regarded as salts in which oxide of ethyle acted the part of a base. Thus, when butyrate of soda was distilled with alcohol and sulphuric acid, the resulting product was regarded as butyrate of oxide of ethyle. The compound ethers are regarded as two atoms of water in which one equivalent of hydrogen is replaced by the radical of an alcohol, and the other by the radical of an acid. In addition to those there are others more closely resembling the simple ethers. They are founded also on the water type, both atoms of hydrogen being replaced by alcohol radicals, but by different individuals. The following formulæ show the chemical constitution of all these varieties placed for comparison in juxtaposition with their type:

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Water (2 eq.)</th>
<th>Common ether</th>
<th>Methyl-ethyle ether</th>
<th>Butyle ether</th>
</tr>
</thead>
<tbody>
<tr>
<td>H (\text{O}^2) C(_2)H(_4)O(_2) C(_2)H(_4)O(_2)</td>
<td>(\text{H} \text{O}^2)</td>
<td>(\text{C}_2\text{H}_4\text{O}_2)</td>
<td>(\text{C}_2\text{H}_4\text{O}_2)</td>
<td></td>
</tr>
</tbody>
</table>

In the above formulæ the first represents the type water. The second common ether, the third the equivalents of ethyle replacing the two of hydrogen. In the third we have a mixed ether, one of the equivalents of hydrogen being replaced by ethyle and the other by methyl.

The fourth illustration is that of a compound ether: one of the hydrogens is there replaced by ethyle, and the other by the oxidized radical of butyric acid.

Ether is largely used in medicine and chemistry. In small doses it acts as a powerful stimulant. Inhaled in quantity it is an anesthetic. It is a most invaluable solvent in organic chemistry for resins, fatty, and numerous other bodies.—C. G. W.

EXOSMOSIS and ENDOMOSIS. As some manufacturing processes involve the phenomena expressed by these two words, it appears necessary briefly to explain them.

When two liquids are separated by a porous sheet of animal membrane, unglazed earthenware, porous stone, or clay, these liquids gradually diffuse themselves; and supposing salt and water to be on one side of the division, and water only on the other, the saline solution passes in one direction, while the water, though with less intensity, passes in another.

Instead of the two words introduced by Dutrochet, Professor Graham proposes the use of the single term Osmose (from ὀσμός), impulsion.

It was supposed that there was, at the same time, an impulsive force acting from without and another acting from within; that there was indeed a current flowing in, and another flowing out. It however appears to be proved that the Osmose between water and saline solutions, consists not in the passage of two liquid currents, but in the passage of particles of the salt in one direction, and of pure water in the other. Professor Graham has observed, that common salt diffuses into water, through a thin membrane of ox-bladder deprived of its outer muscular coating, at the same rate as when no membrane is interposed. This force plays an important part in the functions of life, and it will be found to explain many of the phenomena associated with Dyeing, Tanning, &c.

EXPANSION.—Experiments by Fresnel, Forbes, Powell, Trevelyan, and Nyland, have a tendency to prove that heat occasions a repulsion between the particles of matter at small distances. If a heated poker is laid slantingly on a block of lead at the ordinary temperature, it will commence to vibrate, first slowly, and will increase with such rapidity as to produce a musical note, which continues for some time, usually changing to an octave at the termination. These results would appear to prove a movement amongst the particles constituting the bar.

Some remarkable examples of expansion are furnished by the influence of sunshine on the Britannia Tubular Bridge.

The most interesting effect is that produced by the sun shining on one side of the tube, or on the top, while the opposite side and bottom remained shaded and comparatively cool; the heated portions of the tube expand, and thereby warp or bend the tube towards the heated side, the motion being sometimes as much as 2½ inches vertically and 2½ inches laterally.
While the tubes were supported on the temporary piers on the beach, these motions were easily observed. An arm carrying a pencil was fixed on the south side of the tube, at the centre, and a board was fixed on a post independent of the tube, and at right angles to it; the pencil was pressed against the board by a spring, and the rise and fall, and the lateral motions of the tube, were consequently traced on the board. In this way a very interesting diagram was taken daily. The lowest part of each figure is the starting point, or normal position of the tube, to which the pencil always accurately returns during the night. As soon as the sun rises in the morning it starts towards the right hand, rising obliquely, the top and one side of the tube being warmed, and the bottom and opposite side remaining unaffected. It continues thus till one o'clock, when the sun, having ceased to shine on the southern side, begins to warm the northern side; the top still retaining its high temperature, the tube thus acquires a nearly horizontal motion towards the left hand, the slight descent in the line indicating the diminished effects of the sun on the top as it gradually sinks. The greatest deflection to the left hand is not attained until sunset, after which the tube rapidly descends in a uniformly curved line to its resting point. In the summer time this point is hardly attained before the rising sun compels it to commence its journey anew. When the sun is frequently obscured by passing clouds, very curious diagrams are obtained. During the absence of the sun the tube begins to cool rapidly, and to return to its normal position; every passing cloud is thus beautifully recorded.

The middle of the centre arch of Southwark Iron Bridge rises one inch in the height of summer. When great lengths of iron pipe are laid down for the conveyance of steam or hot water, sliding joints are necessary to prevent destruction either of the apparatus or of the building in which it is placed.

F

FALSE TOPAZ. A light yellow pellucid variety of quartz crystal. It may be distinguished from yellow topaz, for which when cut it is frequently substituted, by its difference of crystalline form, the absence of cleavage, inferior hardness, and lower specific gravity. Found in the Brazils, &c.

FAULTS (Faltés, Fr.), in mining, are disturbances of the strata which interrupt the miner's operations, and put him at a loss to discover where the vein of ore or bed of coal has been "thrown" by the convulsion of nature.
FERMENTATION.

A mineral vein may be regarded as a fissure formed by the consolidation of the rocks in which it exists, or by some movement of the entire mass, producing these cracks at right angles to the line of greatest mechanical force; these have been eventually filled in with the mineral or metalliferous matter which we find in them. After this has taken place, there has sometimes been a movement of a portion of the ground, and the mineral vein, or lode, has been fractured. A simple illustration of this is the preceding, fig. 288, where we have the mineral vein dislocated, and subsequently to the dislocation there has been a formation of a string of sphenoth iron, following the bendings of a crack formed by the movement, which, in this case, has been less than the width of the lode. In the large majority of examples the "heave" or "throw" of the lode has been very considerable. It is usual to speak of a fault as if the fissure had actually moved the lode. It should be understood that an actual movement of great masses of the solid earth is implied, and consequently, the lode having been formed before the movement, it is moved with the rock in which it is enclosed.

Fig. 290 is the plan of veins 1, 2, 3, 4, and an Elvan course a, which have been dislocated along the line b, c, and all the lodes and the Elvan course moved. In this case the movement has probably taken place from the North towards the South. This disturbance will be continued to a great depth, and in fig. 289 is a section showing the dislocation of a lode into three parts. In this case the movement has probably been the subsidence of that portion of the ground containing the lode b, and the further subsidence of that portion containing the lode a; the condition of the surface being subsequently altered by denudation. The inclination of a lode is frequently changed by these movements; thus fig. 291 suggests c d to represent the original condition of the lode; by a convulsion, the portion a b has fallen away, leaving a chasm between, and the " dip" or inclination of the lode is therefore materially changed. The direction of the lode is frequently altered by these movements. Many lodes in Cornwall have a direction from the N. of E. to the S. of W. up to a fault, on the other side of which the direction is changed from the S. of E. to the N. of W. Where these disturbances are of frequent occurrence, the difficulties of mining are greatly increased.

FERMENTATION. (Fermentation, Fr.; Gärung, Germ.) A change which takes place, under the influence of air and moisture at a certain temperature, in the constituent particles of either vegetable or animal substances. This change is indicated by a sensible internal motion—the development of heat—the evolution of gaseous products. Fermentation may be divided into several kinds, as—

Saccharine,  
Glyceric,  
Acetic,  
Butyric,  
Alcoholic or Vinous,  
Lactic,  
Putrefactive,  
Mucous.

Of the latter examples but a brief notice is required. Mucous fermentation is established when the juice of the beetroot or carrot is kept at a temperature of 10° for some time, when a tumultuous decomposition takes place. All the sugar disappears, and the liquor is found to contain a large quantity of gum, and of mannite with lactic acid.

Lactic Fermentation.—If a solution of one part of sugar in five parts of water be made to ferment, by the addition of a small quantity of cheese or animal membrane, at a temperature of 90° or 100°, lactic acid is formed, which may be separated by adding a little chalk, the lactate of lime depositing in crystalline grains. In lactic fermentation mannite invariably is produced as a secondary product, the formation of which is not explained. It has been suggested that the formation of mannite is connected with the production of succinic acid, which Schmidt, in a letter to Liebig, states that he has found in fermenting liquids containing sugar. He suggests the following formula:

\[
\text{C}_2\text{H}_4\text{O}_5 + \text{C}_2\text{H}_4\text{O}_5 = \text{C}_6\text{H}_2\text{O}_7
\]


Glyceric Fermentation.—When glycerine is mixed with yeast, and kept in a warm place for some weeks, it is decomposed and converted into methactonic acid. This fermentation resembles the last named. The glycerine, C\(_2\)H\(_5\)OH, forming metactone acid, C\(_4\)H\(_4\)O\(_4\), as sugar, C\(_3\)H\(_4\)O\(_2\), does lactic acid, C\(_3\)H\(_4\)O\(_2\), by loss of the elements of water.—Kane.

Butyric Fermentation.—If the lactic fermentation is allowed to proceed beyond the point indicated for the formation of lactate of lime, the precipitate in part redissolves with a very copious evolution of hydrogen gas and carbonic acid, and the liquor contains butyrate of lime. In this action two atoms of lactic acid, C\(_3\)H\(_4\)O\(_2\), produce butyric acid, C\(_4\)H\(_5\)O\(_2\), carbonic acid, and hydrogen gas.

Putrefactive Fermentation. See Putrefaction.

The three first named kinds of fermentation demand a more especial attention from their importance as processes of manufacture. Under the heads respectively—Acetic Acid, Beer, Brewing, Distillation, Malt, and Wine, will be found every thing connected with
FERMENTATION.

the practical part of the subject; we have therefore now to deal with the chemical and physical phenomena which are involved in the remarkable changes which take place. When vegetable substances are in contact with air and moisture, they undergo a peculiar change, (decomposition.) Oxygen is absorbed, and carbolic acid and water are given off, while there is a considerable development of heat. This may take place with greater or less rapidity, and thus cremaeosus, fermentation, or combustion may be the result; the spontaneous ignition of hay (as an example) being the final action of this absorption of oxygen.

Saccharine Fermentation.—If starch, C\textsubscript{6}H\textsubscript{12}O\textsubscript{6} + 2H\textsubscript{2}O, be moistened with an infusion of pale malt, it is rapidly converted into dextrine, C\textsubscript{6}H\textsubscript{12}O\textsubscript{6}, and hence into grape sugar, C\textsubscript{6}H\textsubscript{12}O\textsubscript{6}2; this is especially called the saccharine fermentation, since sugar is the result.

Acetic and Alcoholic Fermentation.—If sugar is dissolved in water, it will remain perfectly unaltered if the air is excluded; but if exposed to the air, a gradual decomposition is brought about, and the solution becomes brown and sour. Oxygen has been absorbed, and acetic acid produced. If, however, the sugar is brought into contact with any organic body which is in this state of change, the particles of the sugar participate in the process, carbonic acid is evolved, and alcohol produced. There are some substances which are more active than others in producing this change. Yeast is the most remarkable; but blood, white of egg, glue, and flesh, if they have been putrefied, are capable of exciting fermentation; vegetable albumen and gluten being, however, more active. Vegetable albumen, gluten, and legermin differ from most vegetable bodies in the large quantity of nitrogen which they contain. These substances exist in all fruits, and hence, when fruit is crushed, the sugar of the juices in contact with the albumen or gluten being then exposed to the air, oxygen is rapidly absorbed, the nitrogenous body begins to putrefy, and the sugar passes into fermentative activity. The necessity for oxygen is at the commencement of the decomposition; when the putrefaction of the albumen or gluten has once begun, it extends throughout the mass without requiring any further action of the air. These may be regarded as natural ferments. Yeast is an artificial one. This body will be more particularly described. See Yeast.

To produce a vinous liquid, it is necessary that these shall be present sugar, or some body, as starch or gum capable of conversion into sugar, a certain portion of water, and some ferment—for all practical purposes yeast; and the temperature should be steadily maintained at about 80° F. Both cane and grape sugar yield alcohol by fermentation, but Liebig considers that cane sugar, before it undergoes vinous fermentation, is converted into grape sugar by contact with the ferment: and that, consequently, it is grape sugar alone which yields alcohol and carbonic acid.

Grape sugar, as dried at 212°, contains exactly the elements of two atoms of alcohol and four of carbonic acid. As 2(C\textsubscript{6}H\textsubscript{12}O\textsubscript{6}) and 4CO\textsubscript{2} arise from C\textsubscript{6}H\textsubscript{12}O\textsubscript{6}.

Cane sugar takes an atom of water to form grape sugar. It follows therefore that cane sugar should in fermenting yield more than its own weight of carbonic acid and alcohol; and it has been ascertained by experiment that 100 parts actually give 104, whilst by theory 105 should be produced, consisting of 51.3 of carbonic acid, and 53.7 of alcohol.-(Kowes.)

Dr. Perera has given the following very intelligible arrangement to exhibit these changes:

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 equivalent of crystallized cane sugar</td>
<td>1 eq. of grape sugar</td>
</tr>
<tr>
<td>121</td>
<td>180</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4 eq. carbon 24</th>
<th>4 eq. carbonic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>S = carbon 4%</td>
<td>S = oxygen 61%</td>
</tr>
<tr>
<td>8 = oxygen 61%</td>
<td>17 = hydrogen 17%</td>
</tr>
<tr>
<td>12 = alcohol 92%</td>
<td></td>
</tr>
</tbody>
</table>

These facts will sufficiently prove that vinous or alcoholic fermentation is but a metamorphosis of sugar into alcohol and carbonic acid.

Such are the generally received views. We find, however, some other views promulgated which it is important to notice.

Liebig calls putrefactive fermentation,—every process of decomposition which, caused by an external influence in any part of an organic compound, proceeds through the entire mass without the further cooperation of the original cause. Fermentation, according to Liebig^\textsuperscript{\textdagger}, is the decomposition exhibited in the presence of putrefying substances or ferments, by compounds nitrogenous or non-nitrogenous, which alone are not capable of putrefaction. He distinguishes, in both putrefaction and fermentation, processes in which the oxygen of the atmosphere continually co-operates, from such as are accomplished without further access of atmospheric air.

Liebig opposes the view which considers putrefaction and fermentation as the result of vital processes, the development of vegetable formations or of microscopic animals. He
FERMENTATION.

adduces that no trace of vegetal formations are perceptible in milk which is left for some time in vessels carefully tied over with blotting paper, not even after fermentsation has regenerated a quantity of lactic acid having been formed. He further remarks of fermentative processes, that alcoholic fermentation having been observed too exclusively, the phenomena have been generalized, while the explanation of this process ought to be derived rather from the study of fermentative phenomena of a more general character.

Blondeau proposes the view that every kind of fermentation is caused by the development of fungi. Blondeau states that alcoholic fermentation is due to a fungus which he designates Torvula cerevisiae; whilst another, Penicillium glaucum, gives rise to lactic fermentation. The latter fermentation follows the former in a mixture of 30 grm. of sugar, 10 grm. of yeast, and 200 c. c. of water, which has undergone alcoholic fermentation at a temperature of about 20°, being terminated in about two days. Beer yeast, when left in contact with water in a dark and moist place, contains, according to Blondeau, germs both of Torvula cerevisiae, and of Penicillium glaucum; the former can be separated by a filter, and will induce alcoholic fermentations in sugar water, whilst the latter are extremely minute, and pass through the filter; the filtrate, mixed with sugar water, gives rise to lactic fermentation.

Acetic fermentation is due to the development of Torvula aceti; sugar is converted into acetic acid, without evolution of gas, if 500 grm. dissolved in a litre of water, be mixed with 200 grm. of casein, and confined in contact for a month at a temperature of about 20°. The conversion of nitrogenous substances into fat, (for instance, of casein, in the manufacture of Roquefort cheese; of fibrin under similar circumstances,) which Blondeau designates by the term fatty fermentation, (fermentation adipacea,) is caused by Penicillium glaucum or Torvula viridis; and the former fungus is stated to act likewise in butyric and in urea fermentation, (conversion of the urea into a carbonate of ammonia.)

Opposed to this view Schubert has published an investigation upon yeast. In order to prove that the action of yeast is due merely to its porosity, he finds his investigation upon some experiments of Bredoecke, (particularly in reference to the statement that fermentation taking place in a solution of sugar in contact with porous bodies is due to an impurity of sugar;) according to which various porous bodies, such as charcoal, paper, flowers of sulphur, &c., to which some bitartrate of ammonia is added, are capable of inducing fermentation in a solution of raw sugar. His observations are also based upon some experiments of his own, which seem to indicate that porous bodies, even without the addition of a salt, are capable of exciting fermentation in a solution of (pure?) cane sugar. Whatever may be the means whereby alcoholic fermentation is induced, he states it to be indispensable that the body in question should be exposed for some time to the influence of air, and that oxygen and carbonic acid are absorbed by the ferment. Both oxygen and carbonic acid, being electro-negative substances, stand in opposition to the electro-positive alcohol, and therefore predispose its formation, but only when they are highly condensed by the powerful surface attraction of the yeast, or of any porous body. The electrical tension, he states, may be increased by many salts, provided that the latter do not at the same time chemically affect either the sugar or the ferment.

C. Schmidt has communicated the results of his experiments to the Annalen Chem. Pharm. After stating numerous experiments, he continues: "Nor are fungi the prima movens of saccharic fermentation; the clear filtrate obtained by throwing almonds crushed in water upon a moist filter, soon induces fermentation in a solution of urea and of grape sugar; in the latter case, no trace of ferment cells can be discovered under the microscope, not even after fermentation is fully developed. If the solution, still containing sugar, is allowed to stand eight days or a fortnight after fermentation has ceased, an exuberant development of cellular aggregations is observed, but no putrefaction ensues; the fungi, well washed and introduced into a fresh solution of grape sugar, continue to grow luxuriantly, inducing, however, if at all, but very weak fermentation, which rapidly ceases; hence the growth of fungi during fermentative processes is but a secondary phenomenon. The increase of the resiliury ferment, which occurs after yeast has been in contact with sugar, arises from a development of ferment cellulose, which probably takes place at the expense of the sugar. If muscule, gelatine, yeast, &c., in a very advanced state of putrid decomposition, be introduced into a solution of 1 sugar in 4 water, all phenomena of putrefaction disappear; after a few hours active fermentation sets in, ferment cells being formed, and the liquid contains alcohol, but no ammonia. The inactivity of crushed yeast is due, not to the destruction of the fungi, but to the chemical changes which are induced in yeast during the considerable time necessary for complete comminution. The crushed cells, introduced into sugar water, give rise to the production of lactic acid, without evolution of gas. Schmidt is of opinion that fermentation is a process analogous to the formation of ether. He believes that one of the constituents of yeast, together with the elements of grape sugar, gives rise to the formation of one or several compounds, which are decomposed in statu nascendi, (like sulpho-vinic acid,) splitting into alcohol and carbo-acid.\"
FERMENTATION.

We believe that the preceding paragraphs fairly represent the views which have been promulgated upon the phenomena of change, which are in many respects analogous to those of combustion and of vitality, presented in the fermentative processes. Much has been done, but there are still some points which demand the careful attention of the chemist.

In a practical point of view, the question which arises from the alteration in the specific gravity of the fluid by fermentation is a very important one, a knowledge of the original gravity of beer being required to fix the drawback allowed upon beer when exported, according to the terms of 10 Vict. c. 5. By this act a drawback is granted of 5s. per barrel of thirty-six gallons, upon beer exported, of which "the words used before fermentation were not of less specific gravity than 1-034, and not greater specific gravity than 1-081," and a drawback of 7s. 6d. per barrel upon beer of which "the words used before fermentation were not of less specific gravity than 1-081." The brewer observes the original gravity of his worts by means of some form of the hydrometer, and preserves a record of his observation. The revenue officer has only the beer, from which he has to infer the original gravity. From the great uncertainty which appeared to attend this question, Professors Graham, Hofmann, and Redwood were employed by the Board of Inland Revenue to discover how the original gravity of the beer might be ascertained most accurately from the properties of the beer itself. When worts are fermented, the sugar passes into alcohol, and they lose in density, and assume as beer a different specific gravity. The gravity of the wort is called the original gravity—that of the beer, beer gravity. The report of Graham, Hofmann, and Redwood, upon "original gravities," may be supposed to be in the hands of every brewer; but as some of the points examined materially explain many of the phenomena of vinous fermentation, we have transferred a few paragraphs to our pages:—

"As the alcohol of the beer is derived from the decomposition of saccharine matter only, and represents approximately double its weight of starch sugar, a speculative original gravity might be obtained by simply increasing the extract gravity of the beer by that of the quantity of starch sugar known to be decomposed in the fermentation. The inquiry would then reduce itself to the best means of ascertaining the two experimental data, namely, the extract gravity and the proportion of alcohol in the beer, particularly of the latter. It would be required to decide whether the alcohol should be determined from the gravity of the spirits distilled from the beer; by the increased gravity of the beer when its alcohol is evaporated off; by the boiling point of the beer, which is lower the larger the proportion of alcohol present; or by the refracting power of the beer upon light—various methods recommended for the valuation of the spirits in beer.

"Original gravities so deduced, however, are found to be useless, being in error and always under the truth, to an extent which has not hitherto been at all accounted for. The theory of brewing, upon a close examination of the process, proves to be less simple than is implied in the preceding assumption; and other changes appear to occur in worts, simultaneously with the formation of alcohol, which would require to be allowed for before original gravities could be rightly estimated. It was found necessary to study the gravity in solution of each by itself, of the principal chemical substances which are found in fermented liquids. These individual gravities defined the possible range of variation in original gravity, and they brought out clearly for the first time the nature of the agencies which chiefly affect the result.

"The use of cane sugar is now permitted in breweries, and the solution of sugar may be studied first as the worst of simplest composition. The tables of the specific gravity of sugar solutions, constructed by Mr. Bate, have been verified, and are considered entirely trustworthy. The numbers in the first and third columns of Table I, which follows, are, however, from new observations. It is to be remarked that these numbers have all reference to weights, and not to measures. A solution of cane sugar, which contains 25 grains of sugar in 1000 grains of the fluid, has a specific gravity of 1-0101, referred to the gravity of pure water taken as 1000; a solution of 50 grains of cane sugar in 1000 grains of the fluid, a specific gravity of 1-0593, and so on. The proportion of carbon contained in the sugar is expressed in the second column; the numbers being obtained from the calculation that 171 parts by weight of cane sugar (C\textsubscript{12}H\textsubscript{22}O\textsubscript{11}) consist of 72 parts of carbon, 11 parts of hydrogen, and 58 parts of oxygen; or of 72 parts of carbon combined with 99 parts of the elements of water. It is useful to keep this in view, the proportion of carbon in sugar solutions, as that element is not involved in several of the changes which precede or accompany the principal change which sugar undergoes during fermentation, and which changes only affect the proportion of the oxygen and hydrogen, or elements of water, combined with the carbon. The proportion of oxygen and hydrogen in the altered sugar increases or diminishes during the changes referred to; but the carbon remains constant, and affords, therefore, a fixed term in the comparison of different solutions.
Fermentation.

"Table 1.—Specific gravity of solutions of Cane Sugar in water.

<table>
<thead>
<tr>
<th>Cane Sugar, in 1000 parts by weight.</th>
<th>Carbon in 1000 parts by weight.</th>
<th>Specific Gravity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>10·53</td>
<td>1010-1</td>
</tr>
<tr>
<td>50</td>
<td>21·05</td>
<td>1020-2</td>
</tr>
<tr>
<td>75</td>
<td>31·58</td>
<td>1030-2</td>
</tr>
<tr>
<td>100</td>
<td>42·10</td>
<td>1040-6</td>
</tr>
<tr>
<td>125</td>
<td>52·63</td>
<td>1051</td>
</tr>
<tr>
<td>150</td>
<td>63·16</td>
<td>1061-8</td>
</tr>
<tr>
<td>175</td>
<td>73·68</td>
<td>1072-9</td>
</tr>
<tr>
<td>200</td>
<td>84·21</td>
<td>1083-8</td>
</tr>
<tr>
<td>225</td>
<td>94·73</td>
<td>1095-2</td>
</tr>
<tr>
<td>250</td>
<td>105·26</td>
<td>1106-7</td>
</tr>
</tbody>
</table>

"When yeast is added to the solution of cane sugar in water, or to any other saccharine solution, and fermentation commenced, the specific gravity is observed to fall, owing to the escape of carbonic acid gas, and the formation of alcohol, which is specifically lighter than water; 171 grains of sugar, together with 9 grains of water, being converted into 92 grains of alcohol and 88 grains of carbonic acid, \((C_6H_{12}O_6 + HO = 2CO_2 + 4H_2O)\). But if the process of fermentation be closely watched, the fall of gravity in cane sugar will be found to be preceded by a decided increase of gravity. Solutions were observed to rise from 1055 to 1058, or 3 degrees of gravity, within an hour after the addition of the yeast, the last being in the usual proportion for fermentation. When the yeast was mixed in minute quantity only, such as 1/150 of the weight of the sugar, the gravity of the sugar solution rose gradually in four days from 1055 to 1057-91, or also nearly 3 degrees; with no appearance, at the same time, of fermentation or of any other change in the solution. This remarkable increase of density is owing to an alteration which takes place in the constitution of the cane sugar, which combines with the elements of water and becomes starch sugar, a change which had been already proved by H. Rose and by Dubuqmfaut, to precede the vinous fermentation of cane sugar. The same conversion of cane sugar into starch sugar, with increase of specific gravity, may be shown by means of acids as well as of yeast. A solution of 1000 parts of cane sugar in water, having the specific gravity 1054-64, became with 1 part of crystallized oxalic acid added to it 1064-7; and being afterwards heated for twenty-three hours to a temperature not exceeding 128° Fah., it was found (when cooled) to have attained a gravity of 1067-6—an increase again of nearly 3 of gravity."

The difference between the gravities of solutions of cane sugar and starch sugar are of great practical value, but these must be studied in the original; the result, however, being "that the original gravity of a fermented liquid or beer must be different, according as it was derived from a wort of cane sugar or of starch sugar."

The gravity of malt wort was determined to be intermediate between that of pure cane sugar and starch sugar, and solutions containing an equal quantity of carbon exhibited the following gravities:

- Cane sugar - 1072-9
- Pale malt - 1074-2
- Starch sugar - 1076-0

Two other substances were found to influence the original gravity of the wort: dextrin, or the gum of starch, and caramel. Tables are given of the specific gravities of these, from which the following results have been deduced:

<table>
<thead>
<tr>
<th>Caramel</th>
<th>1062-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dextrin</td>
<td>1066-9</td>
</tr>
<tr>
<td>Starch sugar</td>
<td>1076</td>
</tr>
</tbody>
</table>

Caramel is stated to interfere more than dextrin in giving lightness or apparent attenuation to fermented worts, without a corresponding production of alcohol.

"Another constituent of malt wort, which should not be omitted, is the soluble azotized or albuminous principle derived from the grain. The nitrogen was determined in a strong wort of pale malt with hops, of the specific gravity 1088, and containing about 21 per cent. of solid matter. It amounted to 0·217 per cent. of the wort, and may be considered as representing 3·43 per cent. of albumen. In the same wort, after being fully fermented, the nitrogen was found to amount to 0·134 per cent., equivalent to 2·11 per cent. of albumen. The loss observed of nitrogen and albumen may be considered as principally due to the production and growth of yeast, which is an insoluble matter, at the cost of the soluble albuminous matter. Solutions of egg-albumen in water, containing 3·43 and 2·11 per cent., respectively of that substance, were found to have the specific gravities of 1064-2 and
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1005-1. Hence a loss of density has occurred during fermentation of 1-1 degree on a wort of 1088 original gravity, which can be referred to a change in the proportion of albuminous matter. It will be observed that the possible influence of this substance and of the greater or less production of yeast during fermentation, upon the gravity of beer, are restricted within narrow limits."

The reporters proceed:

"The process required for the determination of the original gravity of beer, must be easy of execution, and occupy little time. It is not proposed, in the examination of a sample, to separate by chemical analysis the several constituents which have been enumerated. In fact, we are practically limited to two experimental observations on the beer, in addition to the determination of its specific gravity.

"One of these is the observation of the amount of solid or extractive matter still remaining after fermentation, which is always more considerable in beer than in the completely fermented wash of spirits. A known measure of the beer might be evaporated to dryness, and the solid residue weighed, but this would be a troublesome operation, and could not indeed be executed with great accuracy. The same object may be attained with even a more servicable expression for the result, by measuring exactly a certain quantity of the beer, such as four fluid ounces, and boiling it down to somewhat less than half its bulk in an open vessel, such as a glass flask, so as to drive off the whole alcohol. The liquid when cool is made up to four fluid ounces, or the original measure of the beer, and the specific gravity of this liquid is observed. It has already been referred to as to the extract gravity of the beer, and represents a portion of the original gravity. Of a beer of which the bitterness was known, the original gravity of the malt wort was 1121, or 121°; the specific gravity of the beer itself before evaporation, 1043; and the extract gravity of the beer 1056-7, or 56-7°.

"The second observation which can be made with sufficient facility upon the beer, is the determination of the quantity of alcohol contained in it. This information may be obtained most directly by submitting a known measure of the beer to distillation, continuing the ebullition till all the alcohol is brought over, and taking care to condense the latter without loss. It is found in practice that four ounce measures of the beer form a convenient quantity for the purpose. This quantity is accurately measured in a small glass flask, holding 1,750 grains of water when filled up to a mark in the neck. The mouth of the small retort containing the beer is adapted to one end of a glass tube condenser, the other end being bent and drawn out for the purpose of delivering the condensed liquid into the small flask previously used for measuring the beer. The spirituous distillate should then be made up with pure water to the original bulk of the beer, and the specific gravity of the last liquid observed by the weighing-bottle, or by a delicate hydrometer, at the temperature of 60° Fahr. The lower the gravity the larger will be the proportion of alcohol, the exact amount of which may be learned by reference to the proper tables of the gravity of spirits. The spirit gravity of the beer already referred to proved to be 982-25; or it was 14-05° of gravity less than 1000, or water. The 'spirit indication' of the beer was therefore 14-05°; and the extract gravity of the same beer, 56-7°.

"The spirit indication and extract gravity of any beer being given, do we possess data sufficient to enable us to determine with certainty the original gravity? It has already been made evident that these data do not supply all the factors necessary for reaching the required number by calculation.

"The formation of the extractive matter, which chiefly disturbs the original gravity, increases with the progress of the fermentation; that is, with the proportion of alcohol in the fermenting liquor. But we cannot predicate from theory any relation which the formation of one of these substances should bear to the formation of the other, and are unable, therefore, to say beforehand that because so much sugar has been converted into alcohol in the fermentation, therefore so much sugar has also been converted into the extractive substance. That a uniform, or nearly uniform, relation, however, is preserved in the formation of the spirits and extractive substance in beer-brewing, appears to be established by the observations which follow. Such an uniformity in the results of the vinous fermentation is an essential condition for the success of any method whatever of determining original gravities, at least within the range of circumstances which affect beer-brewing. Otherwise two fermented liquors of this class, which agree in giving both the same spirit indication and the same extractive gravity, may have had different original gravities, and the solution of our problem becomes impossible."

The following table, one of several of equal value, gives the results of a particular fermentation of cane sugar. "Fifteen and a half pounds of refined sugar were dissolved in 10 gallons of water, making 102 gallons of solution, of which the specific gravity was 1055-3 at 60°; and after adding three fluid pounds of fresh porter yeast, the specific gravity was 1055-05. The original gravity may be taken as 1055-3 (55-3°)."
FERMENTATION.

**Table II.—Fermentation of Sugar Wort of original gravity 1055-3.**

<table>
<thead>
<tr>
<th>Number of Observation</th>
<th>Period of Fermentation</th>
<th>Degrees of Spirit Indication</th>
<th>Degrees of Extract Gravity</th>
<th>Degrees of Extract Gravity lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 0</td>
<td>0</td>
<td>55'30</td>
<td>0°</td>
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<tr>
<td>2</td>
<td>0 6</td>
<td>1'39</td>
<td>52'12</td>
<td>3'18</td>
</tr>
<tr>
<td>3</td>
<td>0 12</td>
<td>2'37</td>
<td>47'82</td>
<td>7'48</td>
</tr>
<tr>
<td>4</td>
<td>0 10</td>
<td>3'60</td>
<td>43'62</td>
<td>11'68</td>
</tr>
<tr>
<td>5</td>
<td>0 23</td>
<td>4'33</td>
<td>40'13</td>
<td>15'17</td>
</tr>
<tr>
<td>6</td>
<td>1 5</td>
<td>5'21</td>
<td>35'50</td>
<td>19'50</td>
</tr>
<tr>
<td>7</td>
<td>1 12</td>
<td>6'26</td>
<td>31'39</td>
<td>23'91</td>
</tr>
<tr>
<td>8</td>
<td>1 19</td>
<td>7'12</td>
<td>27'63</td>
<td>27'67</td>
</tr>
<tr>
<td>9</td>
<td>2 11</td>
<td>8'39</td>
<td>20'26</td>
<td>35'04</td>
</tr>
<tr>
<td>10</td>
<td>3 11</td>
<td>9'87</td>
<td>18'40</td>
<td>41'90</td>
</tr>
<tr>
<td>11</td>
<td>5 12</td>
<td>10'97</td>
<td>7'60</td>
<td>47'70</td>
</tr>
<tr>
<td>12</td>
<td>6 12</td>
<td>11'27</td>
<td>4'15</td>
<td>51'15</td>
</tr>
</tbody>
</table>

**Table III.—Fermentation of Sugar Wort of original gravity 1055-3.**

<table>
<thead>
<tr>
<th>Degrees of Spirit Indication</th>
<th>Degrees of Extract Gravity lost</th>
<th>Degrees of Spirit Indication</th>
<th>Degrees of Extract Gravity lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1'71</td>
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<td>27'01</td>
</tr>
<tr>
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<td>4'74</td>
<td>8</td>
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</tr>
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<td>3</td>
<td>9'26</td>
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</tr>
<tr>
<td>4</td>
<td>13'48</td>
<td>10</td>
<td>42'55</td>
</tr>
<tr>
<td>5</td>
<td>18'30</td>
<td>11</td>
<td>47'88</td>
</tr>
<tr>
<td>6</td>
<td>22'54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In two other fermentations of cane sugar, the degrees of gravity lost, found to correspond to the degrees of spirit indication, never differed from the numbers of the preceding experiment, or from one another, more than 0'9 of gravity lost. This is a sufficiently close approximation.

It is seen from table IV., which is of much importance, that for 5° of spirit indication, the corresponding degrees of gravity lost are 18'3°. For 5'9° of spirit indication, the corresponding degrees of gravity lost are 22'2°.

This table is capable of a valuable application, for the sake of which it was constructed. By means of it, the unknown original gravity of a fermented liquid or beer from cane sugar may be discovered, provided the spirit indication and extract gravity of the beer be observed. Opposite to the spirit indication of the beer in the table, we find the corresponding degrees of gravity lost, which last, added to the extract gravity of the beer, gives its original gravity.

Suppose the sugar beer exhibited an extract gravity of 7°9°, (1007°9,) and spirit indication of 11°. The latter marks, according to the table, 47'7° of gravity lost, which added to the observed extract gravity, 7°9°, gives 55'6° of original gravity for the beer, (1055°6.)

Similar tables are constructed for starch sugar, and for various worts with and without hops.
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"**TABLE IV.—STARCH-SUGAR.**

Degrees of Spirit Indication, with corresponding degrees of gravity lost.

Besides the degrees of gravity lost corresponding to whole degrees of spirit indication, the degrees of gravity lost corresponding to tenths of a degree of spirit indication are added from calculation.

<table>
<thead>
<tr>
<th>Degrees of Spirit Indication</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
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<td>0</td>
<td>—</td>
<td>.2</td>
<td>.3</td>
<td>.5</td>
<td>.7</td>
<td>.9</td>
<td>1.0</td>
<td>1.2</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>1</td>
<td>1.9</td>
<td>2.1</td>
<td>2.4</td>
<td>2.7</td>
<td>3.0</td>
<td>3.3</td>
<td>3.6</td>
<td>3.9</td>
<td>4.2</td>
<td>4.6</td>
</tr>
<tr>
<td>2</td>
<td>5.0</td>
<td>5.4</td>
<td>5.8</td>
<td>6.2</td>
<td>6.6</td>
<td>7.0</td>
<td>7.5</td>
<td>8.0</td>
<td>8.5</td>
<td>9.0</td>
</tr>
<tr>
<td>3</td>
<td>9.5</td>
<td>9.9</td>
<td>10.3</td>
<td>10.7</td>
<td>11.2</td>
<td>11.6</td>
<td>12.0</td>
<td>12.4</td>
<td>12.8</td>
<td>13.3</td>
</tr>
<tr>
<td>4</td>
<td>13.8</td>
<td>14.2</td>
<td>14.6</td>
<td>15.0</td>
<td>15.5</td>
<td>15.9</td>
<td>16.3</td>
<td>16.7</td>
<td>17.2</td>
<td>17.7</td>
</tr>
<tr>
<td>5</td>
<td>18.3</td>
<td>18.7</td>
<td>19.1</td>
<td>19.5</td>
<td>19.9</td>
<td>20.3</td>
<td>20.8</td>
<td>21.2</td>
<td>21.7</td>
<td>22.2</td>
</tr>
<tr>
<td>6</td>
<td>22.7</td>
<td>23.1</td>
<td>23.5</td>
<td>23.9</td>
<td>24.4</td>
<td>24.7</td>
<td>25.2</td>
<td>25.6</td>
<td>26.1</td>
<td>26.6</td>
</tr>
<tr>
<td>7</td>
<td>27.1</td>
<td>27.5</td>
<td>27.9</td>
<td>28.3</td>
<td>28.7</td>
<td>29.1</td>
<td>29.6</td>
<td>30.0</td>
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<td>31.0</td>
</tr>
<tr>
<td>8</td>
<td>32.0</td>
<td>32.3</td>
<td>32.7</td>
<td>33.0</td>
<td>33.3</td>
<td>33.6</td>
<td>34.0</td>
<td>34.3</td>
<td>34.6</td>
<td>35.0</td>
</tr>
<tr>
<td>9</td>
<td>37.2</td>
<td>37.7</td>
<td>38.2</td>
<td>38.7</td>
<td>39.2</td>
<td>39.7</td>
<td>40.2</td>
<td>40.6</td>
<td>41.0</td>
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</tr>
<tr>
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</tr>
</tbody>
</table>

After explaining many points connected with the problem, as it presented itself under varied conditions as it respected the original wort, the Report proceeds:

"The object is still to obtain the spirit indication of the beer. The specific gravity of the beer is first observed by means of the hydrometer or weighing-bottle. The extract gravity of the beer is next observed as in the former method; but the beer for this purpose may be boiled in an open glass flask till the spirits are gone, as the new process does not require the spirits to be collected. The spiritless liquid remaining is then made up to the original volume of the beer as before. By losing its spirits, the beer of course always increases in gravity, and the more so the richer in alcohol the beer has been. The difference between the two gravities is the new spirit indication, and is obtained by subtracting the beer gravity from the extract gravity, which last is always the higher number.

"The data in a particular beer were as follows:

- **Extract gravity,**
- **Beer gravity,**
- **Spirit indication,**

"Now the same beer gave by distillation, or the former method, a spirit indication of 9°. The new spirit indication by evaporation is, therefore, less by 9° than the old indication by distillation. The means were obtained of comparing the two indications given by the same fermented wort or beer in several hundred cases, by adopting the practice of boiling the beer in a retort, instead of an open flask or basin, and collecting the alcohol at the same time. The evaporation uniformly indicated a quantity of spirits in the beer nearly the same as was obtained by distillation, but always sensibly less, as in the preceding instance. These experiments being made upon fermented liquids of known original gravity, the relation could always be observed between the new spirit indication and the degrees of specific gravity lost by the beer. Tables of the degrees of spirit indication, with their corresponding degrees of gravity lost, were thus constructed, exactly in the same manner as the tables which precede; and these new tables may be applied in the same way to ascertain the original gravity of any specimen of beer. Having found the degrees of spirit indication of the beer by evaporation, the corresponding degrees of gravity lost are taken from the table, and adding these degrees to the extract gravity of the beer, also observed, the original gravity is found. Thus the spirit indication (by the evaporation method) of the beer lately referred to, was 9°, which mark 4° of gravity lost in the new tables. Adding these to 1044°, the extract gravity of the same beer, 1087° is obtained as the original gravity of the beer.

The results of the extensive series of experiments made, were, that the problem could be solved in the two extreme conditions in which they have only to deal with the pure sugars entirely converted into alcohol.

"The real difficulty is with the intermediate condition, which is also the most frequent, one, where the solid matter of the beer is partly starch and partly extractive; for no accurate chemical means are known of separating these substances, and so determining the quantity of each in the mixture.

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"But a remedy presented itself. The fermentation of the beer was completed by the addition of yeast, and the constituents of the beer were thus reduced to alcohol and extractive only, from which the original gravity, as is seen, can be calculated.

"For this purpose a small but known measure of the beer, such as four fluid ounces, was carefully deprived of spirits by distillation, in a glass retort. To the fluid, when cooled, a charge of fresh yeast, amounting to 150 grains, was added, and the mixture kept at 80° for a period of sixteen hours. Care was taken to connect the retort, from the commencement, with a tube condenser, so that the alcoholic vapor which exhaled from the wash during fermentation should not be lost. When the fermentation had entirely ceased, heat was applied to the retort to distil off the alcohol, which was collected in a cooled receiver. About three-fifths of the liquid were distilled over for this purpose; and the volume of the distillate was then made up with water to the original volume of the beer. The specific gravity of the lastspirituous liquid was now taken by the weighing-bottle. To obtain a correction for the small quantity of alcohol unavoidably introduced by the yeast, a parallel experiment was made with that substance. The same weight of yeast was mixed with water, and distilled in another similar retort. The volume of this second distillate was also made up by water to the beer volume; its specific gravity observed, and deducted from that of the preceding spirituous liquid. This alcohol was added to that obtained in the first distillation of the beer, and the weight of starch sugar corresponding to the whole amount of alcohol was calculated. This was the first result.

"For the solid matter of the beer: the spirituous liquid remaining in the retort was made up with water to the beer volume, and the specific gravity observed. A correction was also required here for the yeast, which is obtained by making up the water and yeast distilled in the second retort, to the original volume of the beer, and deducting the gravity of this fluid from the other. The quantity of starch sugar corresponding to this corrected gravity of the extractive matter was now furnished by the table. This was the second result.

"The two quantities of starch sugar thus obtained were added together. The specific gravity of the solution of the whole amount of starch sugar, as found in the table, represented the original gravity of the beer.

"This method must give an original gravity slightly higher than the truth, owing to the circumstance that the dextrin, albumen, and salts, which are found among the solid matters dissolved in beer, are treated as having the low gravity of extractive matter, and accordingly amplified by about one-sixth, like that substance, in allowing for them ultimately as starch sugar. The error from this source, however, is inconsiderable. It is to be further observed, that the error from imperfect manipulation, of which there is most risk in the process, is leaving a little sugar in the extractive matter from incomplete fermentation. This accident also increases the original gravity deduced. The process has given results which are remarkably uniform, and is valuable in the scientific investigation of the subject, although not of that ready and easy execution which is necessary for ordinary practice, and which recommends the former method."

"Table V.—To be used in ascertaining Original Gravities by the Distillation Process.

Degrees of Spirit Indication with corresponding degrees of gravity lost in Malt Worts.

<table>
<thead>
<tr>
<th>Degrees of Spirit Indication</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
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<td>0</td>
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<td>2</td>
<td>6</td>
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<td>55</td>
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<td>63</td>
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</tbody>
</table>

For Table V., see page 531.
FERROCYNANIDES.

The compounds of the radical ferrocyanogen. The latter radical is bisbace; when, therefore, it combines with hydrogen to form ferrocyanic acid, it takes up two atoms. These two atoms of hydrogen can be replaced by metals as in ferrocyanide of potassium or prussiate of potash, as it is commonly called. See Prussiate of Potash. Ferrocyanogen consists of CNFe, which may also be written CyFe, or ferroprussic, Cy.

The modes of preparing the ferrocyanides differ, according as the resulting substance is soluble or insoluble in water. The soluble salts, such as those with alkalies, are prepared either by neutralizing hydroferrocyanic acid with the proper metallic oxide, or by boiling prussian blue with the oxide, the metal of which it is intended to combine with the ferrocyanogen. Other methods may also be adopted in special cases. The processes for preparing the ferrocyanides of the alkali metals on the large scale will be described in the article Prussiate of Potash.

When the ferrocyanide is insoluble in water, it may be prepared by precipitating a salt of the metal of ferrocyanide of potassium. Thus, in the preparation of the reddish or purple ferrocyanide of copper,

$$2 \text{Cu}_2\text{O} \cdot \text{SO}_4 + \text{K}_2\text{C}_n \text{y} = \text{Cu}_2\text{Cy} + 2(\text{K}_2\text{SO}_4).$$

The above equation written in full becomes:

$$2 \text{Cu}_2\text{O} \cdot \text{SO}_4 + \text{K}_2\text{C}_n \text{y} \cdot \text{Fe} = \text{Cu}_2\text{C}_n \text{y} \cdot \text{Fe} + 2(\text{K}_2\text{SO}_4).$$

Ferrocyanide of potassium is much used as a test for various metals, in consequence of the characteristic colors of the precipitates formed with many of them. The principal ferrocyanides with their colors and modes of preparation will be found in the following list:

**Ferrocyanide of aluminium.**—An unstable compound formed by digestinghydrate of alumina with ferroprussic acid.

**Ferrocyanides of antimony and arsenic.**—Neither of these salts are known in a state of purity.

**Ferrocyanide of barium.**—This salt may be prepared by boiling prussian blue in slight excess with baryta water and evaporating to crystallization.

**Ferrocyanide of bismuth.**—When a solution of ferrocyanide of potassium is added to a solution of a salt of bismuth, a yellow precipitate is obtained. It becomes of a greenish tint on keeping for some time.

**Ferrocyanide of cadmium** may be attained as a white precipitate on adding a solution of ferrocyanide of potassium to a soluble salt of cadmium.

**Ferrocyanide of calcium** may be prepared in the same manner as that of barium, but, owing to the sparing solubility of lime in water, we must substitute cream of lime for baryta water.

**Ferrocyanide of cerium** is a white salt only slightly soluble in water. Its properties are very imperfectly known.

**Ferrocyanide of chromium.**—The protochloride of chromium gives a yellow precipitate with ferrocyanide of potassium.

**Ferrocyanide of cobalt.**—Salts of cobalt give a pale blue precipitate with ferrocyanide of potassium. It appears to decompose on keeping, as its color becomes altered.

**Ferrocyanide of copper.**—When ferrocyanide of potassium is added to a solution of subchloride of copper, a white precipitate appears, which, on exposure, becomes converted
FILTRATION.

into a purplish red substance, apparently identical with the ordinary ferrocyanide of copper which falls down on the admixture of salts of the protoxide of copper with solutions of ferrocyanide of potassium.

Ferrocyanide of glaucium may be obtained, according to Berzelius, under the form of an amorphous varnish, by decomposing ferrocyanide of lead with a solution of sub硫酸ate of glucina.

Ferrocyanide of hydrogen constitutes ferroprussic acid.

Ferrocyanide of iron, or prussian blue.—This salt exists in several conditions, according to the mode of preparation. The ordinary salt is formed by adding a solution of ferrocyanide of potassium to a solution of a persalt of iron. The following equation explains the reaction that ensues with the sesquichloride:

$$2(\text{Fe}_2\text{C}_2\text{Fe}) + 3(C\text{y}K) = 3(C\text{y}Fe) + 6\text{KCI}.$$

Ferrocyanide of lead is procured as a white precipitate by adding a solution of ferrocyanide of potassium to a salt of lead.

Ferrocyanide of magnesium is probably best prepared by neutralizing ferroprussic acid with magnesia or its carbonate. It forms a pale yellow salt.

Ferrocyanide of manganese may be obtained as a white precipitate, on adding ferrocyanide of potassium to a solution of pure protochloride or protosulphate of manganese.

Ferrocyanide of mercury.—This compound cannot be obtained in a state of purity by precipitation. It has not been sufficiently examined.

Ferrocyanide of molybdenum.—Molybdenum salts give, with ferrocyanide of potassium, a dark brown precipitate soluble in excess of the precipitant. If a salt of molybdic oxide be treated in the same manner, a precipitate is obtained, having a similar appearance, but insoluble in excess. Molybdates in solution give precipitates lighter in color than the last.

Ferrocyanide of nickel is obtained under the form of a pale apple green precipitate, on addition of precipitate of potash to a salt of nickel.

Ferrocyanide of silver.—Ferrocyanide of potassium gives a white precipitate with silver salts.

Ferrocyanide of sodium may be formed by the action of caustic soda on prussian blue.

Ferrocyanide of strontium can be procured precisely in the same manner as the corresponding barium salt, substituting solution of caustic strontia (obtained from the nitrate by ignition) for baryta water.

Ferrocyanide of tantalum has probably never been obtained pure. Wollaston found that tautalic acid (dissolved in binoxolate of potash) gave a yellow precipitate with prussiate of potash.

Ferrocyanide of thorium.—A white precipitate is produced by the action of solution of prussiate of potash on salts of thorium.

Ferrocyanide of tin.—Pure salts of tin, whether of the per- or prot-oxide, give white precipitates with ferrocyanide of potassium.

Ferrocyanides of titanium.—Solutions of titanates give a golden brown precipitate when treated with solution of ferrocyanide of potassium.

Ferrocyanide of uranium.—The protochloride gives a pale, and the perchloride a dark reddish brown precipitate with ferrocyanide of potassium.

Ferrocyanide of vanadium.—Salts of vanadic oxide give pale yellow, and of vanadic acid, rich green precipitates with prussiate of potash.

Ferrocyanide of yttrium.—Chlorides of yttrium gives a white precipitate with ferrocyanide of potassium.

Ferrocyanide of zinc cannot be prepared by precipitation. It may be obtained in the form of a white powder by the action of oxide or carbonate of zinc on ferroprussic acid. — C. G. W. For Ferro-Cyanides, see Ure's Dictionary of Chemistry.

FILTRATION. Mr. H. M. Witt communicated to the Philosophical Magazine for December, 1856, an account of some experiments on filtration, which are of much value. Many of his experiments were made at the Chelsea Water Works, and they appear of such interest that we quote the author's remarks to some extent.

"The system of purification adopted by the Chelsea Water Works, at their works at Chelsea, consisted hitherto (for the supply his by this time commenced from Kingston) in pumping the water up out of the river into subsiding reservoirs, where it remained for six hours; it was then allowed to run on to the filter-beds. These are large square beds of sand and gravel, each exposing a filtering surface of about 270 square feet, and the water passes through them at the rate of about 63 gallons per square foot of filtering surface per hour, making a total quantity of 1087.5 gallons per hour through each filter."

"The filters are composed of the following strata, in a descending order:"

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Rft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Finest sand</td>
<td>2 ft</td>
</tr>
<tr>
<td>2. Coarser sand</td>
<td>6 ft</td>
</tr>
<tr>
<td>3. Shells</td>
<td>0 ft</td>
</tr>
<tr>
<td>4. Fine gravel</td>
<td>3 ft</td>
</tr>
<tr>
<td>5. Coarse gravel</td>
<td>3 ft</td>
</tr>
</tbody>
</table>
Filtration.

These several layers of filtering materials are not placed perfectly flat, but are disposed in waves; and below the convex curve of each undulation is placed a porous earthenware pipe, which conducts the filtered water into the mains for distribution. The depth of water over the sand was 4 feet 6 inches. The upper layer of sand is renewed about every six months, but the body of the filter has been in use for about twenty years.

"Samples of water were taken and submitted to examination:—

"1st, from the reservoir into which the water was at the time being pumped from the middle of the river.

"2d, from the cistern, after subsidence and filtration."

Experiments were made at different seasons of the year; but one of Mr. Witt's tables will sufficiently show the results.

1. Shows the quantities of the several substances originally present, represented in grains, in the imperial gallon (70,000 grains) of water.
2. The amount present after filtration.
3. The actual quantities separated in grains in the gallon of water.
4. The percentage ratio which the amounts separated bear to the quantities originally present.

<table>
<thead>
<tr>
<th></th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Originally present</td>
<td>After filtration</td>
<td>Amount separated</td>
<td>Percentage ratio of separated Matter</td>
</tr>
<tr>
<td>Total solid residue, including suspended matter</td>
<td>55.60</td>
<td>22.85</td>
<td>32.75</td>
<td>58.90</td>
</tr>
<tr>
<td>Organic matter</td>
<td>4.05</td>
<td>1.349</td>
<td>2.70</td>
<td>66.66</td>
</tr>
<tr>
<td>Total mineral matter</td>
<td>51.55</td>
<td>21.501</td>
<td>30.49</td>
<td>58.29</td>
</tr>
<tr>
<td>Suspended matter</td>
<td>28.95</td>
<td>2.255</td>
<td>26.645</td>
<td>92.10</td>
</tr>
<tr>
<td>Total dissolved salts</td>
<td>19.82</td>
<td>10.216</td>
<td>9.54</td>
<td>15.04</td>
</tr>
<tr>
<td>Lime</td>
<td>8.719</td>
<td>8.436</td>
<td>0.293</td>
<td>3.36</td>
</tr>
</tbody>
</table>

"It has been assumed as a principle that sand filtration can only remove bodies mechanically suspended in water, but I am not aware that this statement has been established by experiment; in fact, I am not acquainted with any published analytical examination of the effects of sand filtration.

"These experiments supply the deficiency, and show, moreover, that these porous media are not only capable of removing suspended matter, (80 to 92 per cent.) but even of separating a certain appreciable quantity of the salts from solution in water, viz., from 5 to 15 per cent. of the amount originally present, 9 to 19 per cent. of the common salt, 3 per cent. of the lime, and 6 of the sulphuric acid.

"Taking the purer water from Kingston, two experiments were made simultaneously with the same water, one filtration being through charcoal alone, and the other through sand alone, the sand filter having an area of 4 square feet, and consisting of the following materials:

| | | | | |
|---|---|---|---|
| Fine sand | - | - | - | 1.9 |
| Shells | - | - | - | - | 1.1 |
| Gravel | - | - | - | 1.4 |
| Coarse gravel | - | - | - | - | 9 |

Results of Sand Filtration.

<table>
<thead>
<tr>
<th></th>
<th>After 24 hours' action</th>
<th>After 48 hours' action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original Water basis</td>
<td>After 24 hours' action</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comparison</td>
</tr>
<tr>
<td>Total residue</td>
<td>24.075</td>
<td>22.85</td>
</tr>
<tr>
<td>Mineral salts</td>
<td>20.657</td>
<td>21.159</td>
</tr>
<tr>
<td>Organic matter</td>
<td>3.668</td>
<td>-</td>
</tr>
<tr>
<td>Suspended matter</td>
<td>2.959</td>
<td>0.293</td>
</tr>
<tr>
<td>Cholride</td>
<td>0.962</td>
<td>-</td>
</tr>
<tr>
<td>Cholride of Sodium</td>
<td>1.429</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>After 72 hours' action</th>
<th>After 120 hours' action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original Water basis</td>
<td>After 72 hours' action</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comparison</td>
</tr>
<tr>
<td>Total residue</td>
<td>24.075</td>
<td>22.85</td>
</tr>
<tr>
<td>Mineral salts</td>
<td>20.657</td>
<td>21.159</td>
</tr>
<tr>
<td>Organic matter</td>
<td>3.668</td>
<td>-</td>
</tr>
<tr>
<td>Suspended matter</td>
<td>2.959</td>
<td>0.293</td>
</tr>
<tr>
<td>Cholride</td>
<td>0.962</td>
<td>-</td>
</tr>
<tr>
<td>Cholride of Sodium</td>
<td>1.429</td>
<td>-</td>
</tr>
</tbody>
</table>
"Apart from its special interest, as compared with the following experiment, made simultaneously through charcoal, the following points are in themselves remarkable in the results obtained by this filtration through sand:

"1st. That the filter continued increasing in efficacy even till the conclusion of the experiment, i.e., for 376 hours, not having lost any of its power when the experiment was terminated.

"2d. That no weighable quantity of dissolved organic matter was removed by the sand in this experiment; but it must be remembered that the quantity originally present was but small.

"3d. Its power of removing soluble salts was considerable; as a maximum, 21 per cent. of the common salt being separated."

Results of Charcoal Filtration.

<table>
<thead>
<tr>
<th></th>
<th>Original Water used.</th>
<th>After 72 hours' action.</th>
<th>After 144 hours' action.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total residue</td>
<td>24.573</td>
<td>22.143</td>
<td>2.448</td>
</tr>
<tr>
<td>Mineral salts</td>
<td>23.687</td>
<td>21.375</td>
<td>2.312</td>
</tr>
<tr>
<td>Organic matter</td>
<td>0.906</td>
<td>0.765</td>
<td>0.138</td>
</tr>
<tr>
<td>Suspended matter</td>
<td>3.509</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.862</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chloride of Sodium</td>
<td>1.420</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

After 249 hours' action:  

<table>
<thead>
<tr>
<th></th>
<th>After 249 hours' action.</th>
<th>After 256 hours' action.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total residue</td>
<td>24.573</td>
<td>20.821</td>
</tr>
<tr>
<td>Mineral salts</td>
<td>23.687</td>
<td>-</td>
</tr>
<tr>
<td>Organic matter</td>
<td>0.906</td>
<td>0.759</td>
</tr>
<tr>
<td>Suspended matter</td>
<td>3.509</td>
<td>-</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.862</td>
<td>-</td>
</tr>
<tr>
<td>Chloride of Sodium</td>
<td>1.420</td>
<td>-</td>
</tr>
</tbody>
</table>

On comparing this experiment with the preceding, the following point comes out as showing the difference between the effects of sand and charcoal as filtering media.

By the charcoal, speaking generally, a considerably larger quantity of the total residue contained in the water was removed than by the sand, their maximum results being respectively as follows:—

<table>
<thead>
<tr>
<th>Amount originally present.</th>
<th>Amount separated in Grains in the Gallon.</th>
<th>Amount separated in percentage of the Quantity present.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>By Sand.</td>
<td>By Charcoal.</td>
</tr>
<tr>
<td></td>
<td>By Sand.</td>
<td>By Charcoal.</td>
</tr>
<tr>
<td>24.573 grains in the gallon</td>
<td>2.074</td>
<td>3.757</td>
</tr>
</tbody>
</table>

Mr. Way has also shown that agricultural soil possesses the power of separating the soluble salts and organic matter from water in a remarkable manner. There are without doubt many natural phenomena which are immediately dependent upon this power, possessed by porous bodies of all kinds, in a greater or a less degree.

FLAT RODS. In mining, a series of rods for communicating motion from the engine, horizontally, to the pumps or other machinery in a distant shaft.

FLAX. After pulling, the treatment of flax varies in different countries. In Russia, part of Belgium and Holland, and in France, the plant after being pulled is dried in the sun, being set up on the root end in two thin rows, the top interlacing in the form of the letter V inverted. The sun and air soon thoroughly dry the stems, and they are then made into sheaves, and the seed afterwards beaten off. The stems are steeped subsequently. Another mode, in general use in Ireland and in part of Flanders, is to steep the green stems immediately after they are pulled. In Flanders, the seed is invariably separated from the stems before the latter are immersed in water. In Ireland, although this is practised to some extent, yet the great bulk of the flax crop is put in the water at once, with the seed capsules attached, and consequently there is a very considerable annual loss to the country by this waste of a most valuable product of the plant. In the Walloon country of Belgium, in its eastern provinces, and in the greater part of Germany, dew-setting is practised. That is, in place of immersing the stems in water, they are spread thinly on short grass, and the action of the dews and rains ultimately effects what immersion in a running stream or pool accomplishes in a much shorter time, namely, the decomposition of the gum which binds the fibres to the stem and to each other. Fibre obtained by this method is, however, of very inferior quality and color.
The Flax.

If the fibre of flax be separated from the stem without the decomposition of this matter, it is found to be loaded with impurities, which are got rid of afterwards in the wet-spinning, the boiling of the yarn, the subjection of the woven fabric to the action of an alkaline lye, and the action of the atmosphere,—of rains and of alternate dippings in water, acidulated with sulphuric acid, and of a solution of chloride of lime, which are all required to perfect the bleaching. The great object, therefore, is to obtain the fibre as nearly free from all foreign substances as possible, and, consequently, the mechanical separation of it from the woody pith of the stem is not to be recommended.

At various periods attempts have been made to prepare flax fibre without steeping. Weak acids, solutions of calcium peroxide, and of soda, soap, lye, and lime, have all been tried, but have all been found objectionable. In 1815, Mr. Lee brought before the trustees of the linen and hempen manufactures of Belgium "his system of separating the fibre without steeping. He alleged that a large yield was thus obtained, that the coloring matter could afterwards be discharged by the most simple means, and that the fibre possessed greater strength. But it was found that the system was practically worthless. In 1816, Mr. Pollard, of Manchester, brought forward a plan of the same nature, and proposed to make an article from flax, which could be spun on cotton machinery. This also fell to the ground. In France and Belgium, at different periods, similar projects were found equally impracticable. In 1850, and again in 1857, Mr. Doull revived the same, but the same fatal objections prevented the success of the system. The fibre was loaded with impurities, and the apparently larger yield over steeped fibre, consisted solely of these very impurities, which had to be got rid of in the after processes of manufacture. At the same time it must be recognized that the "dry separated" fibre can be rendered useful for one class of manufactures, viz., those where no bleaching is necessary, and its great strength is here an object. For ropes, rick-covers, tarpaulins, railway-wagon covers, &c., where pitch or tar are used, and prevent the decomposing action of moisture and of atmospheric changes, this most objectionable flax fibre is highly useful.

The immersion of the flax stems in water, either as pulled full of sap, or after drying, appears, as yet, to be the best mode of effecting the decomposition of the gum, and obtaining the fibre pure or nearly so. The water most suitable for this purpose is that obtained from surface drainage, springs generally holding more or less of mineral matters in solution. Spring water from a calcareous soil is peculiarly unsuitable, the carbonate of lime which it contains being adverse to the putrefactive fermentation of the vegetable extractive. In Russia much of the flax grown is steeped in lakes. In Holland, it is always steeped in pools filled with the surface drainage. In France and Belgium, it is either steeped in pools or rivers. In England and Ireland generally in pools, though occasionally in rivers. The most celebrated steep-water in the world is the river Lys, which rises in the north of France, and flows through the west of Belgium, joining the Escaut at Ghent. Although the water of this stream has been analyzed, chemists have not been able to discover why it should be so peculiarly favorable to the steeping of flax. All along its course flax is steeped. The trade is in the hands of factors, who purchase the dried stems from the growers, and undertake all the after processes, selling the fibre to merchants when it has been prepared for sale. The apparatus in use consists of wooden crates, 12 feet long, 6 wide, and 3 deep. The sheaves of flax-straw are placed erect in the crates, and the short ends of one are tied to the top ends of another, to secure uniformity of packing. The crate, when filled, is carried into the river, and anchored there, the upper part being sunk, by the weight of stones, 6 inches underneath the surface. The period of steeping begins in May, and ends about September. The previous year's crop is thus steeped, having lain over in the state of dried straw during the winter. All the flax thus treated produces fibre of a yellowish white color, very soft and lustrous, with very finely divided filaments, and strong. From it almost exclusively is made cambric, the finest shirtings, and damask table-linen. It is a strange fact that flax straw is brought to the Lys, from a great distance, and even from Holland, as no other water has yet been found to give such good fibre.

In 1817, a new system of steeping was introduced in Ireland, by Mr. Schenck, of New York. It had been successfully tried in America on hemp, and the inventor crossed the Atlantic to try its efficacy on flax. His plan consisted in hastening the putrefactive fermentation of the vegetable extractive by artificially raising the temperature of the water to 90° Fahrenheit. By this means, instead of an uncertain period of seven to twenty-one days being required for the steep, according to the state of the weather, and the temperature of the atmosphere, the flax was retted uniformly in sixty hours. The flax straw, after the separation of the seed, is placed in wooden or brick vats, and the heat is communicated by forcing steam into a coil of iron or leaden pipes, placed under a false bottom perforated with holes.

The annexed plan (fig. 292) of a retting on Schenck's system, capable of consuming annually the produce of 400 acres of flax, and employing, in all the operations of seed, steeping, drying, and sorting, 30 men and 65 girls and boys, or an aggregate of 95 persons, will give an idea of the arrangements. The seedling-house requires to be of large size,
as flax straw is a bulky article. It is on the ground floor, for the convenience of carting in the flax. The loft above it is used for cleaning and storing the seed. The vat and spreading-rooms are in a building of one story only, built with a vaulted roof resting on pillars.

That part of the roof which is over the vats has lower windows to aid the escape of the vapors from the vats. The drying sheds at the top of the plan are on an open space, well exposed to the wind, and fifty or sixty feet apart. The hot-air rooms or desiccating house are fire-proof, each room capable of containing the flax turned out in one day's work. The scutch mill, with engine and boiler-house, complete the plan.

The advantages of this system were so manifest that it was speedily adopted in many parts of the United Kingdom and of the Continent. It was found, however, to have some defects. The small quantity of water soon became thoroughly saturated with the products of decomposition, and the fibre of the flax when dried, was, consequently, found loaded with a yellow powder, offensive to the smell, causing inconvenience in the preparing and spinning, and worse still, acting prejudicially on the quality of the fibre itself, rendering it harsh and dry.

To obviate these defects, Mr. Pownall, of London, conceived the idea of pressing the flax straw, immediately when taken out of the steep, between a pair of smooth cast-iron cylinders, while, at the same time, a stream of water played upon the rollers. By these means the foul water of the vat is pressed out of the flax stems, which are flattened and bruised, thus tending to aid the separation of the bundles of fibres into minute filaments, while the stream of water effectually washed away all remaining impurities.

It has recently been found that better fibre can be obtained by reducing the temperature and extending the time of steeping. The most perfect adaptation of Schenck's system is at the rettery of M. Auguste Scrive, near Lille, and fig. 293 is a representation of it. Tanks of wood or stone are used, each to contain two and a half tons of flax straw. The straw is classified according to quality and length before being packed in the tank. It is put in erect, the root ends resting on the perforated false bottom, and slightly pressed together, but not so much as to prevent a free circulation of water, and a free exit for the gases germinated by the fermentation. The tank being filled with water, the whole is secured at the tops of the sheaves by narrow strips of wood four inches thick, a, catching the tops on the whole length of each row of bundles. These strips of wood are kept firm by cross-iron holders b, secured by iron bars c, fastened to pieces of wood a, worked into the side walls of the tank, leaving a surface of four inches deep of water over the top of the flax. When the tank has been filled with cold water through the wooden shoot e, the whole is rapidly heated to 78° Fahrenheit, by means of steam pipes coiled under the false bottom. A second open shoot f, carries heated water at 90° to discharge on the surface,
besides two closed pipes a o, one of which brings hot water of the same temperature, and the other cold water. When fermentation sets in, which is ordinarily in eight hours, the pipe, as well as the shoot of water at 90°, is set at play—the first to create a continual current of fresh water through the mass of flax, clearing off the products of decomposition, and bringing them to the surface; the second to drive this foul water to the openings n n, where it is discharged by the overflow. The two pipes with heated and cold water going to the bottom of the tank, as well as the two shoots containing cold and hot water, to go to the surface, are also made use of to equalize the temperature during the whole operation, which is ascertained by the use of a thermometer in the square wooden box j j. The steeping of coarse straw requires 36 to 48 hours, medium qualities 56 to 60 hours, and the finer descriptions 60 to 72 hours. The "wet-rolling" between cylinders after the steep, is accompanied by a shower of water at 70°, not on the flax but on the top of the cylinders. This removes the remaining impurities, and prepares the straw for being easily dried. The heated water may be obtained from the waste water of a spinning-mill, or from a condensing steam-engine.

Flax steeped by Schenck's system is dried in various ways. Some retters have drying-houses with heated air, others set up the flax loosely on the root end, in the field, or spread it thinly on the grass, while others, again, clasp it between two slender pieces of wood about a yard in length, and hang these up in a building open on the sides, so that a current of atmospheric air is constantly passing through.

In 1852, another mode of retting flax was introduced by Mr. Watt, of Glasgow. Instead of immersing the stems in water, he subjected them to the action of steam. Square iron chambers were employed, in which the flax straw was packed. The door by which it was introduced was then fastened by bolts or nuts, and steam was then driven in. The steam penetrated the stems of the flax and being partially condensed on the top and sides of the iron chamber, a constant drip of water, lukewarm, fell upon the flax. In twelve to fourteen hours the stems were removed, and, after being dried, the fibre readily separated from the woody core, the water remaining in the iron chamber being of a dark brown color, without offensive odor. The fibre obtained by this method was of a grayish color, and was at first well thought of by manufacturers; but in the end, on more extended trials, it was found to possess several defects, and Watt's system is not now carried out.

Another system of treating flax was introduced by M. Clausen, a Belgian, and for some time it attracted much attention. He separated the fibre from the stem without steeping, and then by the employment of acids and alkalies, he got rid of the vegetable extractive and other impurities, and produced a fibrous mass strongly resembling cotton. He professed to make an article capable of being spun with cotton or wool. The higher value of flax fibre, however, was a great obstacle, and at present the only use made of his process is
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to convert scutching tow—the refuse flax fibre—into an article to be spun with wool, and even this is practised to but a very small extent.

Messrs. Burton and Pye's patent (fig. 294) is a modification of the hot water steep. By

this process, the flax straw, after the seed is removed, is passed through a machine composed of plain and crimping rollers, by the combined action of which the woody part is rendered easily separable from the fibre. The latter is then placed in a vat, holding about a ton, which is subsequently filled with cold water. This vat has a perforated false bottom, under which steam, with a pressure of 50 lbs. to an inch, is introduced and disseminated by perforated tubes. Another tube conveys into the vat a cold mixture of fuller's earth in water. The introduction of the mixture and the steam is continued until the liquid in the vat reaches 80° Fahrenheit. The flax remains in it at this temperature for thirty hours, when the surface of the liquid is covered with a saponaceous froth. Then an apparatus of cross bars of wood, closely fitting into the interior of the vat and pressed by two powerful screws, expresses the impurities from the fibre. The supply of the fuller's earth is stopped, and cold water is alone supplied with the steam, so regulated that the temperature is by degrees raised to 150°, the pressure being continued until the water appears free from impurities. The water is then withdrawn from the vat through a valve in the bottom, and a pressure equal to 200 tons is applied to the mass of the flax. It remains under this pressure for four hours, when it is half dry. It is then taken out and dried in sheds open at the sides to the air. The fibre produced by Mr. Pye's method appears of good quality and strong, but the system has not as yet been carried out on a sufficiently large scale to admit of a decided opinion on its merits.

The same may be said of the plan of M. Terwangue, of Lille, who employs hot water at a temperature of 15° to 17° centigrade, 60° Fahr., in which chalk and charcoal have been placed. His process requires seventy-two hours on the average, and he employs brick tanks. The water is, as in all the preceding cases, heated by steam.

Before leaving the subject of steeping, reference may be made to a process patented by Mr. F. M. Jennings, of Cork, by means of which coarse flax fibre is rendered capable of being subdivided into minute filaments, or, in other words, made fine. While the fibre of cotton is incapable of subdivision, that of flax, as viewed through the microscope, is seen to consist of a bundle of extremely delicate filaments adhering together, so that fine and coarse flax are really relative terms. Mr. Jennings throws down upon the flax fibre, as it appears in commerce, a small quantity of oil, say half an ounce to the pound of fibre. He effects this by boiling the fibre in an alkaline soap lye, washing with water, and then boiling in water slightly acidulated with pyroligneous acid which decomposes the soap and leaves its fatty constituent on the fibre. It is afterwards washed once more, and is then found to be soft and silky, and the coarse fibres capable of being readily separated on the hackle, while
the strength is not apparently reduced. There is also a greater facility in the bleaching of the linen made from flax fibre so treated, and less loss in weight in the bleaching process.

While some of the inventions referred to for hastening and equalizing the time of steeping are being carried out to a considerable extent, and promise well, when brought to a greater degree of perfection by experience in practical working, to be yet more largely employed, the great mass of the flax grown throughout the globe is steeped in pools, rivers, or lakes. It will, therefore, be most advisable to follow the processes, as practised by the growers or factors.

When the flax has been sufficiently retted, i.e., when on taking a few stalks out of the water the fibre can be readily separated by the fingers along its entire length from the woody interior, it is removed from the water and placed to drain on the banks of the pool or river. It is then taken to a closely shorn grass-field or old pasture land and spread thinly and evenly on the ground. In Flanders, however, the system of drying is somewhat different. Instead of being spread flat on the ground, the sheaves are divided into four portions, and these are set upright in capelles, i.e., the butt ends are spread widely out in a circle on the ground, and the tops are kept close together. By this means the sun and air soon dry the flax. When thoroughly dried it is tied up in sheaves, and after remaining a few days in the usual form of a grain stack it is ricked. In this state it may remain for years without the fibre being deteriorated.
The next process is termed scutching, (French, teillage,) and is intended to separate the fibre from the woody matter of the stem, and thus to make it fit for the spinner. The first part of this process is to bruise the stems thoroughly so that while the fibre, from its tenacity, is intact, the brittle woody part is flattened and broken in such a manner as to admit of its easily being beaten off by the action of the scutch-blade or scutch-mill. In most countries the bruising is done by hand. In Flanders and France the flax straw is first laid flat on the ground, the sheaf being untied and spread thinly, and the workman, placing his foot upon it, beats it with an instrument called a mail, having a curved handle and a heavy square indented mallet, fig. 296.

The next part of the process is to give the flax repeated blows in a machine termed a brace or braque, fig. 297. This is generally made of wood, but sometimes of iron, and consists of two rows of grooves \( \tau \), the upper one moving on a pivot at the socket \( s \). A stout pole \( p \) runs from end to end of the upper row of teeth. The latter are wedge-shaped, \( 4 \frac{1}{2} \) inches deep, \( \frac{1}{4} \) inches thick at top, and \( 3 \frac{1}{4} \) inches long from the head \( \pi \) to the socket \( s \). The head weighs about 8 lbs. and is 10 inches long, and \( 3 \frac{1}{4} \) inches thick. The lower row of teeth consists of four, while the upper is three, fitting into the interstices. The best wood for the machine is that of the apple-tree.

Next comes the scutching proper, still following the Belgian, French, and Dutch method of hand-work. After the flax has been bruised by the mail, and crushed by the braque, it is ready for the scutching process. In Belgium and France the method pursued is by the employment of a wooden stand, (fig. 298.) A broad plank of pine or beech, about 4 feet high, and rather more than a foot broad, about \( \frac{3}{4} \) inch thick, is fixed in a wooden sole \( n \). 3 feet from this sole is a cut in the wood of the upright plank, about \( 1 \frac{1}{2} \) to 2 inches wide. This cut serves for the introduction of a handful of the flax straw, bruised as before de-
acribed, and the workman, holding it three-fourths exposed through the slit, beats it with a tool called the scutch-blade, fig. 299. It is made of walnut wood, and is very tough and flexible. In Ireland the system of scutching by hand is very rude, and prevails chiefly in the western counties. A brake similar to that of Belgium is employed, but instead of the Belgian scutch tool, a rude instrument is employed, generally of ash-wood, in the form of a sword blade.

It must be stated that the system of hand-scutching is only to be recommended where the quality of the flax fibre is so superior as to render economy in waste of primary importance, or else where the wages of labor are so low, as to render the power of machinery of little consequence, as regards economy. But, where wages are high, and flax of medium or low quality, there is no question that machine scutching is the most advisable and the most economical. This has been especially recognized in Ireland, where, in 1827, 1837 scutch mills were in operation, when the growers sent their crops to be prepared for market, at a reasonable rate, much less than hand scutching would have cost. Scutch mills have been introduced with advantage into Russia, Prussia, Austria, Denmark, Holland, Belgium, France, Italy, and Egypt. In Ireland, although in several districts flax is scutched by hand, machine or mill scutching has been for more than half a century in operation. As in the hand-scutching, the operation consists of two processes: first, the bruising of the stems, and secondly, the beating away of the woody parts from the fibre. The original system of bruising is still very general. It consists of a set of three smooth wooden rollers, one underneath and the two others above it, parallel to each other, and one of them horizontal to the lower roller. The laborer sits opposite the lower roller, and inserts a handful of flax straw between the latter and the upper one, which is horizontal to it. The flax being drawn in and bruised between these, passes up between the two upper rollers, and reappears at the outside. It is again put through once or twice, according to its thickness, or to its being more or less steeped, and the fibre, consequently, more or less easily freed from the ligneous part. The scutching apparatus consists of a wooden shaft, to which are attached, at intervals, like radii of a circle, short arms, to which are nailed the stocks, which are parallelogram-shaped blades of hard wood, with the edges partially sharpened. The laborer stands beside an upright wooden plank, very similar to that figured in the description of the Belgian hand-scutching apparatus, and through just such a slit exposes one half of the handful of bruised flax straw to the action of the stocks, which revolve with rapidity along with the shaft, and strike the flax straw, beating off the ligneous matter and leaving the fibre clear. When the end exposed to the stocks is cleaned, the workman turns the handful and exposes the other end. It is usual to have a set of either two or three men at as many different stands, and, instead of each thoroughly clearing out the handful of flax, he only partially does so; the second
then takes it up and finishes it; or, if there be three in the set, he does not quite clean it, but hands it over to the third to do so. In the latter case, the first workman is called the auger, the second the middler, and the third the finisher. The motive power in these scutch-mills is generally water; in some cases they are wind-mills, and in a few instances they are driven by horses. Latterly the use of steam engines has considerably increased, as being more to be depended upon than water, which frequently fails in a dry season. It has been found that the woody waste produced in the scutching is quite sufficient fuel for the boiler, without its being necessary to purchase coal or peat, and this waste had hitherto been applied to no useful purpose, being with the greatest difficulty decomposable for manure.

The first improvement on this old scutch-mill apparatus was the introduction, by Messrs. MacAdam Brothers, of Belfast, of a machine for bruising the flax straw, prior to steeping, and it has since been extensively employed with very satisfactory results. It consists of a series of fluted rollers, running vertically on each other, the flutings varying in width, the widest set being the first through which the flax straw passes, and the others diminishing in width, until the finest is the last. While acting strongly on the ligneous matter, at the same time bruising and crimping it and reducing it almost to powder, it does not injure or disarrange the fibre. One breaking machine of this construction is capable of supplying 12 scutching stands of the ordinary mill. It is attended by two boys, one to feed the flax straw into the machine by means of a feeding table, and the other to remove it at the opposite extremity. Once passing through the machine it is quite sufficient to prepare the flax straw thoroughly for being scutched. The force required to drive it is one horse-power. Fig. 300 will best show its construction and mode of action.

It having been found that many disadvantages were inherent in the old scutch-mill, several persons have set themselves to work to supply a machine which would reduce the cost of labor, obviate the necessity of obtaining skilled workmen, and diminish the great waste of fibre, which was but too frequent in the ordinary mill. Among the most successful of these scutching machines is an invention of Mr. MacBride, of Armagh, Ireland, figs. 301, 302. It consists of a cast-iron frame, at each end of which is a compartment, enclosing a double set of beaters of peculiar construction, which revolve rapidly in a contrary direction, striking alternately on each side of the flax, as it is submitted to their action, and thus removing the woody part, which falls down in dust into a pit or hollow under the machine. In order to carry the flax gradually through the machine and present it in a proper manner to
the beaters, in succession, an endless double rope is introduced, carried in the hollow of a large grooved wheel, in which it is kept tight by means of tension weights. The flax straw, made into handfuels, is introduced at \( a \), under the double rope at one end of the machine, and is at once grasped by it firmly, rather above its middle, and carried along slowly, by the movement of the grooved wheel until it enters, hanging downwards, the compartment \( b \), containing the first set of beaters. By the time the flax straw has been carried through them, all its lower half, which has been exposed to the action of the beaters, is cleaned out, and the rope passing on a short way farther, arrives at a point where a second grooved wheel is revolving, furnished with ropes in like manner, but arranged at a rather lower level. By a simple arrangement, the flax is here transferred from one set of ropes to the other, the second set grasping it near its lowest end, thus leaving all the uncleansed part, or upper half ready to be scutched. The second wheel moves on and carries the flax towards the compartment containing the second set of beaters, cleansing all the upper portion of the flax. It then issues out at \( d \), cleaned throughout, and is received by a person placed there for that purpose, who makes it up into the usual package for sale, 10 lb. A constant succession of similar handfuls of flax straw are thus kept passing through the machine without interruption. \( e \) \( k \) are the beaters, \( f \) \( f \) are two cones, carrying a leather band which gives the motion to the ropes, or carrying apparatus. By shifting the position of this band towards one end or the other of the cones, the speed of the carrying ropes may be varied at pleasure, so as to keep the flax a longer or shorter time under the beaters. Some kinds of flax require more scutching than others. \( o \) \( o \) are the driving pulleys, for giving motion to the machine, by means of a band from motive power, which may be steam, water, wind, or horses. Each pair of pulleys drives one set of beaters separately from the other set, and hence, if requisite to drive one set faster than the other, which is sometimes the ease when the top end of the flax is hard to clean, this is easily done by using a similar pulley on the machine or a larger drum on the driving shaft. \( i \) \( i \) are the tension weights and levers for keeping tight the carrying ropes. \( j \) \( j \) are beaters of wood for carrying the frame of the machine. \( k \) \( k \) are pits underneath the compartments containing the beaters and are for receiving the woody dust as it falls from the flax straw. The machine occupies a space of 11½ feet, by 10 feet, but Some space is required round it for handling the flax. The height of the machine is 5½ feet. The power required is three-horse.

M. Mertens, of Ghent, Belgium, has invented a scutching machine, which merits notice. It is portable and cheap, and requires the attendance of only boys or girls, to put the flax straw in, and take the scutched fibre out. The action is something similar to that of the Irish scutch-mill, but the bruised flax straw is placed in iron clasps, one end being first cleaned out, and then the clasps opened, the flax straw reversed, and a second insertion in the machine cleans out the other end.

Messrs. Rowan, of Belfast, have very recently introduced a scutching machine, whose action differs from all hitherto in use. The flax straw is not previously bruised, but is at once fastened in iron clasps, which are placed in a slide, the action of the machine carrying them on along one side, while two parallel bars of iron, toothed, comb the straw, and separate the woody part from the fibre. The first portion of these bars have coarse teeth, and the teeth become closer by degrees up to the end of the slide. There a workman or boy takes out the clasps, unscrows the nuts fastening them, and reverses the position of the straw, so that the portion not previously subjected to the action of the machine is now presented to it, while that already cleaned out is untouched. The machine is double, \( i \), \( e \), has two sides of combs, each capable of containing twelve of the clasps, and each cleaning out one end of the flax straw. Hence after the workman or boy has unlashed the half-cleaned straw, turned it upside down and presented the uncleaned end to the other side of the machine, the same action of combing, already described, clears out that end thoroughly, and by the time the progressive movement of the mechanism brings the slide to the extreme end, the flax fibre appears free from woody refuse, and in a fit state for market. It is then unclasped, and made up into bundles.

There have been a great number of other scutching machines invented, but it is not necessary to particularize them.

In the operation of scutching, however carefully it may be done by hand or by machine, there occurs more or less waste; \( i \), \( e \), the beating of the flax straw, in order to separate the marketable fibre from the useless wood, causes a portion of the former to be torn off in short filaments mingled with the wood, and this torn fibre is very much less valuable than the long filaments when finally cleared out. In general, it will not average more than an eighth or a tenth of the value of the long fibre. It is termed scutching-tow or codilla, and when properly cleaned is dry spun for yarns employed in making coarse sacking, tarpaulins, &c. Being very much mixed with the woody matter of the flax stems, it is necessary to get rid of the latter before the scutching-tow can be spun into yarn. To accomplish this, shaking by hand is the process, and subsequently the stuff is put into a woody machine termed a "devil," in which, by a mechanism something resembling the shakers in a threshing machine, the woody particles and dust are got rid of. The tow is sorted into different qualities, and in some cases it is "hackled" before being sold. In France and Belgium, it is
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chiefly retained at home, spun by hand, and woven into such fabrics as coarse trousers and shirts, for the laboring classes, aprons, table-covers, &c., &c. What is produced in Russia, is partly used for similar purposes among the serfs, but the great mass is exported, Great Britain and Ireland being the chief mart, and Dundee especially.

The great aim, in all the different methods of scutching, has been to obtain the largest possible yield of long fibre from the flax straw, and to waste as little as possible in scutching-tow. The French and Flemish system of hand-scutching is most successful in this respect, but as the quality of fibre there produced is very much finer, and consequently more valuable than all others, the additional expense of hand labor is compensated by the larger yield of long fibre; whereas, in Ireland, the fibre being generally coarser and less valuable, occupying an intermediate place between the Flemish and Russian, the cheapness of mill-scutching turns the scale, and, except in remote districts, it is now universal. In Egypt, until some fifteen years ago, the method of scutching was of the most primitive form. The fellows, after steeping their flax in the Nile, and drying it on the banks, proceeded to clean out the fibre, by first beating the straw between two flat stones, and then striking it against a wooden post. Meheutci Ali and his successors, however, introduced Irish scutch-mills, driven by steam-power, and since then a marked improvement has taken place in the state in which Egyptian flax has been brought to market. It may be interesting to note here that, in the early period of Egyptian civilization, the dwellers by the Nile were able to manufacture cumbries of a finer texture than the most finished modern mechanism can produce,—as is evidenced by the cerecloths wrapping the mummies, and that from a fibre so coarse in comparison to European flax, that while the latter may be spun by machinery to 900 or 400! less, and by hand to 1200 less, the former cannot be put higher than 40 to 50 less, and rarely even to that.

In the scutching operation, three several matters are obtained from the flax stems. The first is the fibre, which is the primary object, and which is the really valuable portion, that known as **flax.** In commerce The second is the woody refuse of the stems, hitherto applied to no other use than as fuel, or occasionally in Ireland, as a cow's, or occasionally in potatoes, when planted, to protect them from frost. Mr. Pye, of Ipswich, however, proposes to make it available as an auxiliary food for cattle, having the authority of Professor Way that a sample analyzed by him yielded 7-02 per cent. of oil and fatty matter; 7-93 of albuminous matter, (containing 1-25 nitrogen,) and 26-29 starch, gum, sugar, &c. He (Mr. Pye) recommended its use for feeding live stock, in conjunction with ground oats or other farinaceous food. Professor Hodges, nevertheless, in analyzing another sample of this ground lignaceous matter, gave quite a different result, his estimate of the nutritive constituents being as follows:—nitrogenized flesh-forming matters, 3-23 per cent.; oil and fatty matters, 2-91; gum and soluble matters, 14-66; and he compared this with the average results of seven analyses of oil cake, giving nitrogenized matters, 28-47; fatty matters, 12-20; gum and other soluble matters, 39-01.

The third portion separated by the scutching process is termed *scutching-tow,* in Ireland; in Russia and Prussia, "codilla;" in France and Belgium, "etoupe de teillage," described above. These branches of the trade consume annually many thousand tons, imported chiefly from Scotland, from Russia and Prussia. In France, Belgium, and Holland, the codilla or scutching-tow is chiefly retained by the growers or factors at home, for domestic manufacture of similar goods, and of coarse blouses and trousers. It has also been employed for conversion, by Claussen's process, into a finely divided mass of fibres, capable of being mixed with wool and spun along with it into yarn, the fabric made from this yarn being chiefly hose. Before proceeding to treat of the processes to which flax fibre is subjected subsequent to scutching, it may be well to glance at the uses to which the seed is applied. This valuable product of the plant furnishes two articles of much utility, and of very extensive use,—the oil and the cake. When the seed has been separated, dried, and threshed out, it is either sold again for sowing or for conversion into cake and oil. Of course the former purpose only consumes a small proportion of the seed produced throughout the world, and in many countries it is not of a quality suitable to the chief flax-growing localities. Thus, while Northern Russia, Germany, the Low Countries, and France either export seed for sowing, or consume their own produce to a considerable extent for this purpose; the southern provinces of Russia, the states along the Mediterranean, Egypt, Turkey, Greece, and the East Indies, while large exporters of seed for crushing, cannot sell any for sowing. The supply of the seed crushers of the United Kingdom is more largely obtained from Russia and Hindostan than from any other countries. The entire annual import of seed into the British Islands averages 600,000 to 800,000 quarters, value between a million and a half and two millions sterling. The conversion of flax seed into oil and cake is carried out by different methods. In France, Belgium, Holland, and the north of Europe generally, where a large quantity is crushed, the apparatus employed is very simple and yet very effective. Lille, in France, Courtrai and Ghent, in Belgium, Nurem, in Prussia, and the province of Holstein are the great seats of this manufacture. See LINSEED.
The seed is pounded in a kind of wooden mortars, cut out of solid timber, and at the bottom lined with thick copper. By means of a revolving shaft, furnished with projecting notches of wood, beams of oak 20 feet high, the ends shed with channelled iron, are alternately raised up and let fall into the mortars, where, in a short time, they convert the seed into a pulpy mass. When sufficiently pounded, this is then removed, and put into wooden bags, which are then wrapped up in a leathern case lined with a hard-twisted web of horsehair, covering both sides and ends, but open at the edges. These are then ready to be pressed, and for this purpose are packed perpendicularly in an iron receptacle, narrow at the bottom, and widening towards the top. Packings of meal are then put in, and in the course of the bags is inserted a beech wedge. A beam similar to that employed in pounding the seed is then set in motion, and at each descending stroke it drives the wedge in tighter, thus squeezing the bags of seed against the iron sides of the press. When the wedge has been driven home, another is introduced and battered by the beam, until it will drive no farther. At the bottom of the press are holes through which the oil thus pressed out of the seed runs into a receptacle beneath. In order to loosen the wedges and admit of the bags being removed from the press, a wedge of a different form, wide at bottom and narrow at top, and already a fixture in the press, but raised up and fastened by a rope during the driving of the other wedges, is released from the rope, and another beam drives it home, thus partially starting the differently constructed wedges and loosening the mass. The bags come out, and the latter, having worked off the wax of the oil while subjected to so considerable a pressure, is found in a thin hardish cake, taking the form of the leathern case, and off it the wooden bag is readily stripped by the workman's hands. The oil obtained by this process is the purest and most limpid; but another process has to be performed before the seed yields all that the pressure is capable of extracting from it. The cakes, therefore, when taken out of the bags, are broken up and put into the mortar, where the same pounding operation takes place. When again brought into a comminuted state, the powder is put into a circular iron pan or kettle, under which is a fire, and slowly roasted in it, being kept from burning by means of an iron arm which is moved round inside by the machinery, constantly turning the ground seed. When sufficiently warmed by this operation, during which it is made to part more freely with the oil, the mass is again filled in bags and pressed as before, after which they are finally, the bags being stripped off, pared at the edges, put in a rack to dry, and stored for sale. The oil thus obtained is darker in color than that by the cold process, and contains more mullaginous matter. Many foreign oil-millers, however, only employ the hot plan, believing that they have thus a larger yield than when the cold pressure is first used.

In England, the cold pressure is little, if at all, practised, the seed being almost invariably warmed before pressure. The system of crushing, formerly universal here, had some resemblance to the Flemish method above detailed, the chief difference being in the mode of preparing the seed, prior to its being put in the press. The first process is to pass slowly from a hopper, the whole seeds into a pair of smooth or fluted metal rollers which, in turning on each other, crack the seeds. Heavy edged stones then grind them into a meal, a little water being added during the operation, which facilitates the comminution of the seed. The meal is then put in the kettle before described, and while heated and stirred in it, the water mixed with it is evaporated. It is then bagged and put in the press, where the stampers, falling on the wedges, effect the desired results. The most recent improvement in the mode of pressure, and one now largely adopted is the hydraulic press, and it is generally considered that a larger yield of oil can be obtained by its use than by the wedge and stumper-beam method. Blundell's (of Hull) patent is that most generally employed, and Messrs. Samuelson of that place are distinguished as makers of it, having introduced themselves some modifications and improvements. The oil obtained from flaxseed or linseed, as it is generally termed, is of very extensive use in the arts, and is the chief vehicle for paints. To suit it for this purpose, and to make it dry quickly, it is mostly boiled in an iron pan, and during the operation a quantity of limehusk is dissolved in it. The cake is a very favorite article with stock-feeders, being combined, as containing much nutriment in small bulk, with roots or other vegetable food, having large bulk with small nutriment. So extensively is it consumed in Great Britain, that besides the very large quantity made from imported seed, fully 80,000 tons of foreign cake are annually imported. On the continent inferior qualities of cake are ground to a coarse powder, and either spread to the soil as a top-dressing, or steeped in a liquid manure, and the mass spread out on the land in that state. Scutched flax fibre appears in the market made up in different ways. Russian is in large bales or bundles; Dutch and Flemish in bales weighing 2 cwt., the fibre being tied in "heads," each of which is about as much as the hand will grasp. Irish is made up in bundles termed "stones," the weight of which is either 160 lbs. or 240 lbs. In this state it is piled in the street of the spinner, care being taken that it be placed on a ground-floor, bagged or tiled, and not in a boarded loft, as the humid atmosphere of the former is conducive to the preservation of the suppleness and "spinning quality" of the fibre, whereas it deteriorates considerably when exposed to a drier air.
The first operation which it undergoes in the spinning factory is **hackling**.

This process is required to comb and straighten the fibres, to get rid of any knots, and to lessen and equalize the size of the filaments. The action of the hackles necessarily divides the scutched flax into two portions, the long, straight ones, which remain after the flax has passed through the operation, being termed "line," and the woolly or cottony-looking mass which remains, being designated "tow." Both of these are spun, but the line produces the finer and better qualities of yarn, and is consequently much more valuable than the tow. The great object, therefore, is to obtain the largest possible quantity of the former from a given weight of scutched flax, and the yield of line varies considerably according to the nature of the season. Spinners, therefore, are anxious as each new crop of flax is brought to a marketable state, to test the yield of line, so as to guide them in their purchases. They are thus enabled to ascertain more clearly the suitability of the samples for "warp" or "weft" yarns, and for thread-twisting. Warp-yarns being those which constitute the long threads of a linen fabric, require to be harder and stronger than weft-yarns, which form the cross or short threads.

The yield of line as well as the general economy of the operation, is, of course, greatly dependent on the nature of the hackling machine employed, and great scope for care and ingenuity is thus given to the machine-makers. A great number of hackling machines have, from time to time, been brought out, employed in the factories, and subsequently abandoned, when others, having greater merit, have been invented.

In the early period of the linen manufacture, when spinning was done exclusively by hand, no hackling machines were employed. The process was exclusively effected by hand.
hackles. Even after the introduction of machine-spinning, they were, for a long period, the sole means of hackling. Of late years, the machine has been more and more brought into use, and although hand-hackling still exists to a considerable extent, the other method is by far the more extensively employed.

A machine which came into quite extensive use was Combe's reversing cylinders, fig. 303. These machines are constructed in a great variety of forms for different kinds of
FLAX.

work, and seem to give very good results. They are simple in their construction, and give little trouble, acting lightly on the flax and making very wavy fibres. They are made of all sizes from 12 to 30 inches in diameter, and with 4, 6, or 8 gradations of hackles, according to the kind of work to be done on them. The flax is hackled on each side, or each graduation of hackles, by reversing the direction of the rotation of cylinders. The tow, or short fibre, is thrown off the hackles by stripper rods, placed between the rows of pins.

The next machine to be named is by the same inventor, and is styled the patent reversing sheet hackling machine. It is for long line, on the same principle as that just described, except that it has the hackles fixed on flat sheets, as in the "old flat" machine. It is simple and complete; easily driven and attended, and a considerable number are now in use. From the hackles being on a flat sheet, it is necessary to make the holders descend, first on one side while the sheets are moving in one direction, and then on the other while they are moving the other way. This is done by supporting the channels which carry the holders on four levers fixed on two oscillating shafts, to which motion is communicated by a shaft. The holders are slid through by a lever on the top, which acts on a sliding bar, by means of a ball, which forms a universal joint and actuates the holders, whatever position the channels are in. The drawing here given, fig. 304, will show the mechanism.

Both the machines last described are made double, or in fact, the construction of each is that of two machines in one. The table for filling and changing the flax in the holders is attached to the machine. One side hackles one end of the flax, and the other side the other end.

We now have to describe a machine for hackling cut line, patented by Mr. Lowry, of Manchester, and now extensively in use at home and on the continent. It is virtually a modification of Wordsworth's machine, already described.

Fig. 305 is a side elevation of a sheet hackling machine to which these improvements are applied; fig. 306 is an end elevation of the same; fig. 307 is a front view; and fig. 308 an end view of one of Lowry's improved hackle bars. In figs. 305, 306, a a represent the belts, sheets, or chains to which the hackle bars b are attached. These belts, sheets, or chains pass around the small drums e e, and larger drums d d, which are turned round by the gearing, shown in the drawing, or by any other suitable arrangement of gearing. The hackle bars b are made with a recess to receive the stock of the hackles c.

The hackle bars b are connected to the belts, sheets, or chains a a, by means of rivets or screws, passing through the flanges b, and through the belts, sheets, or chains e e; and at each end of each hackle bar is a stud or guide pin d, which, when the hackles arrive near the small drums e e, take into the groove in the guide plates. The object of these guide plates is to support the hackle bars in passing over the small rollers c, and during the operation of striking into the strick of flax or other fibrous material to be operated upon. The holders with the sticks depending from them, are placed within the rails f f, and these
1. The JEI material is proven to be the most efficient in the whole process. The approach proved to be successful in Leeds, where it is used to place a shaft through a set of eccentric buffers. The eccentric buffers complete the cycle, and the shaft is dished to ensure that the purpose of removing the short fibres and extraneous matter is achieved.

2. Another great advantage resulting from this improved mode of attaching the hackle bars is that the hackles can be made to enter the fibrous material at a point closer to the holder than in any of the sheet machines now in use. When the hackles are passing round the drums, they are cleansed by the revolving brushes, which deposit the material removed from the hackles on to the card drums. These drums are cleansed or dopped by the combs, or in any other convenient manner.

3. This machine is also used to a very large extent, and well liked for dressing half line and full length flax. For this purpose the sheets require to be made six inches longer from centre to centre, and the head or trough to lift 6 inches higher, and the top rollers to approach and recede from each other simultaneously with the rising and falling of the head.

Combs, of Belfast, has recently produced another edition of Wordsworth's machine. Its novel feature consists in dispensing with bars altogether, in carrying the hackles and in fixing them directly on the leather sheets. By this means a very true action is obtained, and the working parts are so light, that the machine bears any speed with scarcely any wear and tear. In this invention there are also combined convenient modes of regulating the lift and severity of the cutters to suit different kinds of flax, and the holders are carried through the machine by a separate apparatus for that purpose, while they are at their highest elevation, instead of during the whole process of lifting, as had always been the case in other machines.

A machine has been lately invented, and brought out by Sir J. Fairbairn and Co., of Leeds, called Heilman's tow-combing machine, (fig. 309), which, on trial, is much approved of. The tow is first carded in the ordinary way, say on a breaker card, and then on a finisher card; the latter delivers the tow in the shape of a sliver into cans, which are next placed at the back or back of the tow-combing machine.

From the cans the tow goes to the back conductor, divided into as many compartments as there are slivers; and from the conductor n, to the feeding-box c suspended on shaft n, without being keyed to it. The front lip v of the feeding-box is fitted and fitted with leather, and a corresponding nipper v hung from the same shaft n, and keyed upon it, completes the jaw which has to hold fast the tow, while the cylinder a combs it.

The feeding-box c derives its motion from the nipper v, which is moved by lever and eccentric as shown, and follows that nipper by its own weight, until stopped by india-rubber buffers ii; when the nipper v in going further back leaves it, and the jaw z opens for more tow to be fed, and the tow already combed to be drawn through the detaining comb i, as explained hereafter.

The top z of feeding-box is movable up and down, by means of the connecting rod t,
As shown in the drawing, the top of the feeding-box is fitted with hackles passing through two grates $o$ and $r$, fast on bottom of feeding-box, and leaving between them a space through which the sliver has to pass.

By the above arrangement, the hackles are caused to withdraw from the tow, while the whole box is drawn backwards on slides of table $q$, by the eccentric motion $r v v$. The last backward motion takes place while the jaw $i$ is yet shut, and the top of the box up; but when the latter has got closed again, then the whole box slides down on the table $q$ to its former position, bringing with it the sliver of a quantity equal to that moved: this completes the feeding motion.

Now as the feeding-box recedes, the lip $e$ comes nearer to the combing cylinder $a$, the hackles $s$ are cleaning the tow projecting outside the nipper $f$. As soon as they are passed through, the feeding-box comes back to the most forward position, when the nipper $f$ leaves it, and the jaw $e f$ opens; at the same time the two rollers $t v$ have reached their top position. The top one $t$ is then thrown forwards (by the lever arrangement shown in $v v v$) upon the leather $w$, stretched on parts of surface of cylinder $q$; this roller $v$ is thus driven, and takes hold of the points of the tow presented to it by lips or bottom jaw $e f$; a fine detaining comb $i$ being just before interposed between them to keep back the noils that have not been carried off by the combing cylinder.

In that way the points of the tow are driven upon the sheet $x$, until the roller $t$, by being thrown back again off the leather $w$, their motion is stopped at the same moment, the two rollers $u$ and $v$ are allowed to drop down by eccentric $v$, drawing with them (through the detaining comb $i$, and quite out of the rest of the sliver) the other ends of the fibres of which they have got hold.

While this has been going on, the feeding-box has advanced the sliver a step, the nipper closed, and forced the said feeding-box forwards so as to bring the lip $e$ within the reach of hackles $s$ on cylinder $q$, which then met it, cleansed the tow, and so on as before.

At that time the rollers $t$ and $u$ come up again, and during that upward motion the latter ends of the fibres partly combed and overturned by the cylinder hackles, as shown in drawing, are combed by them in their turn. Then the roller $t$ is once more driven round by the leather $w$ stretched on cylinder, the new points place themselves above the back ends.
FLY POWDER.

of the fibres combed before, and are carried forwards into a continuous sliver on the leather sheet \( x \), from the leather sheet to the rollers \( z z \), then to the trumpet conductor \( x \), the front delivery roller \( c \), and (when more than one head to the machine) from \( c \) to the end delivery \( c \), over the conducting plate \( d \).

In \( e \), \( f \), \( g \), and \( h \), are the usual brush, doffer, comb, and tow box for the noils.

These combing machines are made of different sizes to suit all sorts and lengths of tow; the yarn produced from them is much finer than that produced by the ordinary carding system alone. The combed tow can generally be spun to as high numbers as the line from which it has been combed, and in some instances has produced good yarn, even to higher numbers. The combed tow, after the combing machine, is passed through a system of drawing, roving, and spinning, similar to that used for cut line.

Combe, of Belfast, has lately introduced an improvement in the roving frame. It consists in the application of a peculiar expanding pulley, instead of the cones or discs and runners which have hitherto been always used for the purpose of regulating the "take-up" of the bobbins. It is evident that a strip of 2 or 3 in. broad, working over the cones, placed with the small end of one opposite the large end of the other, is an imperfect and rude mechanical contrivance, and that there must be a constant straining and stretching of the belts. There is the same imperfection attending the disc and runners. The expanding pulley is free from these objections, as its acting surface is a line, and therefore it works with the greatest accuracy, while it is also a great simplification of the machine generally. In rovings for flax and tow it is generally driven directly from the front roller, by which means a large number of wheels and shafts are avoided.

FLUVIATILE. (fluvius, a river,) belonging to a river.

FLY POWDER. Under this name they sell on the continent the black-colored powder obtained by the spontaneous oxidization of metallic arsenic in the air. Various preparations of white arsenic are used for the same purpose in this country. King's yellow is much used; it should be made by boiling together sulphur, lime, and white arsenic, but much that is sold is merely arsenic and sulphur mixed.

Objecting on principle to the familiar use of arsenic and dangerous substances, a preference may be given to a substitute for the above, made by boiling quassia chips into a strong decoction and sweetening with loaf sugar. This seems to have deadly power over the flies,
FOUNDING.

who can scarcely quit the liquid without imbibing a deadly poison, and they are seen to fall from the ceilings and walls of the rooms soon afterwards. Many of these compounds for killing flies are supposed by their odor to attract flies into the rooms.

The inconvenience to manufacturers and others from flies, may be obviated in many cases where apartments are required to be kept as free as possible from them, by reference to facts recorded by Herodotus, of fishermen surrounding themselves with their nets to keep off the gnats. We are indebted to William Spence, Esq., F.R.S., for some very curious particulars respecting the common house fly communicated in a paper to the Entomological Society. The common house fly will not in general pass through the meshes of a net. The inhabitants of Florence and other parts of Italy are aware of this fact, and protect their apartments by hanging network up at the windows, thus at all times the doors and windows may be kept wide open by hanging a light network over the aperture; the meshes may be of considerable width, say enough for several flies on the wing to pass through, and no fly will attempt to pass, unless there be a strong light, (another window opposite, or reflection from a looking-glass.) A knowledge of this simple means of protection from flies on the wing may prevent inconvenience from these intruders, and obviate the necessity for poisons to destroy them.—T. J. P.

FOUNDING. In foundries attached to blast-furnaces, where from 20 to 30 tons of iron are made per diem, the moulds are generally mere troughs cut in the sand in which the melted metal flows and cools in contact with the air. The surfaces of the castings made in this manner present appearances which vary according to the quality of the iron.

The kinds of iron adapted for foundling purposes are those which are most fluid when melted, with which contain most carbon, and are called Nos. 1 and 2. They are distinguished by the surface of the pig of iron, which was exposed to the air during cooling, being smooth, and presenting a slightly convex figure. The surfaces of Nos. 3 and 4 pig iron, and of the white crystalline pig iron (most suitable for making wrought iron) present a concave figure, and the surfaces are very irregular and pitted with holes. The color of the fractures and the closeness of the grain, also indicate the proportion of carbon in pig iron.

The mixtures of metal, melting temperatures of metal, &c., require the closest observation on the part of the workmen and foremen who practise iron founding, and these mechanics are in the practice of observing differences so minute that they cannot be appreciated by the chemist, or expressed in words.

Machinery has enabled the modern foundry, by means of railways, turn-tables, travelling cranes, and steam-power, to move at will the heaviest masses without confusion and with great expedition; but nothing but the traditions of the factory, and the constant habit of observation will enable him to conduct properly the melting and casting of metal so as to arrive at certain results.

This is proved by the constant failures of those who undertake to make descriptions of castings, of which they have had no previous knowledge.

Each branch of foundry work must be studied in detail, and we can only pretend to indicate those directions in which progress has been and is being made.

POUNDING.—The process of iron smelting and the construction of furnaces having been described under other heads, the remaining part of the business of a foundry, viz., that which relates to the preparation of the moulds and moulding, will now be described.

Moulding.—The art of moulding is one of the most important processes carried on in a foundry, and the success of the founder is directly proportioned to the skill and ingenuity brought to bear upon the production of the patterns and the system of moulding.

Before metals can be cast into the variety of shapes in which they are wanted, patterns must be prepared of wood or metal, and then moulds constructed of some sufficiently infusible material capable of receiving the fluid metal, and retaining it without uniting with it until it has solidified.

A mixture of sand and loam (packed tightly into metal boxes, called flask) is generally chosen as the material for making moulds, and is employed advantageously for several important reasons.

Flasks.—In modern foundries a system has been invented, by which flasks of any dimensions may be constructed by means of bolting together a number of rectangular frames of cast-iron, so arranged as to admit of being easily connected together.

When the particular castings for which the flask has been constructed, or rather compounded, are completed, the separate pieces are unbolted, and are ready to be combined in some new form appropriate to the dimensions of the pattern next to be moulded in them.

The loss of capital, &c., invested in flasks, only occasionally used, is thus saved, as well as a loss of time in searching for the size required. The space devoted, on the old system, to the reception of flasks belonging to a foundry was very large, and this may now be appropriated to other purposes.

Sand and loam.—Founders formerly used, on account of price, the description of sand most accessible to them, but at the present time the convenience and cheapness of railway carriage have enabled special qualities of sand to be delivered to all parts of England.
FOUNDOING.

For founding purposes sand is much improved by the admixture of coke, crushed and reduced to a fine powder, and a mill for this purpose is as necessary in every large foundry as those for grinding and mixing loam.

Moulding sand must be a mixture of a large quantity of silex and a small quantity of alumina—the property of the latter material being to cement the grains of silex together. Loam consists of the same materials mingled in opposite proportions.

The preparation of loam for those purposes for which sand is not adapted, is an important duty in a foundry, for a great quantity of loam cores have to be made and dried in proper ovens, which is a tedious operation.

Many castings, such as the screws for steamers, are more conveniently cast in moulds constructed of wet loam. These are shaped to the required form when the clay is moist, and then carefully dried afterwards.

Other castings are of such peculiar shapes that they can only be produced in moulds that take in a vast number of pieces. These moulds are then formed of a number of pieces of hardened sand, held together by strips of iron or of plaster, if the sand used is not coherent enough of itself.

Compounds of silex and alumina are very infusible, and when moistened with water and faced with carbo-naceous matter, they are capable of receiving the most delicate impressions from the patterns which the founder employs.

The moulds of sand are so irregular in shape themselves that they leave innumerable irregular spaces between them, and these intervals form a network of channels which permit the rapid escape of the gases, which are so violently generated by the contact of hot metal falling upon wet sand.

Machine Castings.—Every year, engineers order castings to be prepared of more difficult and complicated forms, and with greater perfection of surface than they have required before.

The reason of this is, that with the progress of the mechanical arts, larger and stronger machines are continually being introduced. In these machines greater steadiness of cast-iron framework is necessary, than can conveniently be obtained when the frame is made out of a number of pieces of iron cast separately and then bolted together. It would be impossible to mould large frames with pieces projecting on all sides, (prepared to receive the moving parts of the machines,) and jutting out in contrary directions, in any flasks filled with wet sand, for the pattern never could be removed without destroying the impression.

To meet these difficulties the modern iron founder has had to follow those plans which were first proved practicable by those who have devoted themselves to casting bronze statues.

In founding, as in so many other branches of manufacture, the discoveries made in prosecuting the fine arts have been advantageously adopted by those engaged in works of utility.

False Cores.—The introduction of the drawbacks, or false cores, made of sand pressed hard, (and admitting of taking to pieces by joints, at each of which a layer of parting sand is prepared,) used for figure casting, enables the moulder to work at his leisure, without fearing that his mould may tumble to pieces, and also enables him to fashion these drawbacks or cores into the most complicated forms, with the power to remove them while the pattern is removed, and build them up again round the empty space (formerly occupied by the pattern) with the greatest facility and accuracy.

The workmen whose occupation is to knead the sand into the forms required by the founder, are termed moulders, and they form a very numerous body of mechanics, demanding and receiving high wages.

The moulder has often only his sand, his flasks, ennes, and a few simple tools, (for smoothing rough places, and for repairing the places in the sand, where the mould has broken away during the lifting of the pattern;) he has to make proper arrangements for the exit of the atmospheric air which leaves the mould as the fluid metal takes its place; and he is expected to produce an exact copy in metal from any pattern, simple or complicated, which may be brought before him.

It will be evident that to produce a good result with such imperfect appliances as the ordinary moulder uses, a skilful workman must be employed, and time expended in proportion to the difficulty of the operations to be performed.

Where only a few impressions from a model are required, it is not worth while to spend money in making expensive patterns, or providing those appliances which may enable patterns to be moulded with facility and little skill; but where thousands of castings are wanted of one shape, it is expedient to spend money and skill on patterns and tools, and reduce the work of the moulder to its minimum.

Management.—The best managed foundry is not that in which good castings are obtained by the employment of skilled workmen at a great expense, and without trouble or thought on the part of the principal, but rather that in which the patterns have been constructed with a special reference to their being cast with the minimum of skill and the maximum of accuracy. It is only by the forethought and calculation of the manager that subsequent operations can be reduced to their smallest cost; and in the foundry, as in all
other manufactories, the true principles of economy are only practised where the head work of one person saves the manual labor of a large number.

Improvements.—The attention of founders has been turned—1st, to the methods by which the labor of making moulds in sand might be reduced; 2d, to the introduction of improvements in the mode of constructing patterns and moulds; and 3d, to the manufacture of metallic moulds for those purposes for which they could be applied. A great progress has been made during the last twenty years in these different directions.

Machine Moulding.—In the large industry carried on for the production of cast-iron pipes for the conveyance of water and gas, machinery has been applied so that the operation of pipe-moulding is performed almost without manual labor, with great rapidity and precision. The cost of pipes at the present time is only about 21. per ton above the value of pig iron, out of which they are made—a sum very small when it is considered that the iron has to be remelted, an operation involving both a cost of fuel and a loss of 5 to 20 per cent. of the iron in the cupola. An ingenious machine for moulding in sand spur and bevel wheels of any pitch or diameter has been employed in Lancashire; the advantage being that the machine moulding-tool acts directly upon the sand without the intervention of any pattern or mould. In any large foundry there is an enormous accumulation of costly wheel-patterns, taking up a great deal of space, and these can now be dispensed with by substituting the wheel moulding-machine. Railway chairs are moulded in a machine; and ploughshares, which, although only weighing a few pounds each, are sold at the low rate of 8d. a ton, are moulded in a machine.

Plate Casting.—Under the next class of improvements the introduction of plate-casting has been the most fruitful of good results.

One great source of expense and trouble in a foundry is the injury done to patterns and to their impressions in the sand by the necessity, under the ordinary system of moulding, of striking the pattern, or pushing it first in one direction and then in another in order to loosen it. Now, the object of the machinist is to construct all his spindles, bearings, bolts, and wheels, of specified sizes, and then to cast the framing of his machine so accurately that the working parts may fit the frame without any manual labor. In order to effect this, every projection and every aperture in the casting must be at an exact distance, and this can only be attained by employing such a system as that of plate-casting, where the pattern is attached firmly to a plate, and it is impossible for the mould to distort or injure the impression. Plate-casting has been long known, but was practically confined for many years to the production of small articles, such as cast nails and rivets.

In a plate-mould for rivet-casting, the shafts of the rivets are attached to one side of the plate, which is $\frac{3}{4}$ in. thick, and planed on both sides. The heads of the rivets are on the opposite side of the plate. The guides on the upper and lower flasks admit the plate to fit between them, and when the plate is withdrawn the upper and lower flask close perfectly, and are in all respects like ordinary moulders’ flasks. The principle of moulding is very simple, and can be performed without skilled labor ten times as fast as ordinary moulding.

![Diagram of Plate Casting](image)


and with far greater accuracy. The plate is inserted between the upper and lower flasks, and sand is filled in; the plate is then withdrawn by simply lifting it; the guides prevent any shaking in this operation; when the flasks are closed the impression of the head of each rivet is exactly perpendicular to its shaft. The first expense of patterns and plates of this description is large, but the accuracy and rapidity of the process of moulding is so advantageous as to cause us to look to the applications of plate-casting becoming very extensive, since the requirements of the machine-maker demand every year better castings at lower prices.

When both sides of a pattern are symmetrical, one-half only need be attached to the smooth plate, the other face of the plate being left blank. An impression of the pattern
must be taken off, both in the upper and lower flask, and when these are united the result will be the same as if both sides of the plate had been moulded from. For unsymmetrical patterns both sides of the plate must be employed. The system of using plates with apertures in them, through which patterns could be pushed and withdrawn by means of a lever, was first employed in casting brass nails. A modification of this system has been extensively employed at Woolwich for moulding shot and shells, in the following manner:

**Shell Casting.** A circular aperture is made in a horizontal plane plate of iron, two inches thick. Through this a sphere of iron, of the same diameter as the aperture, is pushed until exactly a hemisphere appears above the plate. The lower flask is put on to the plate, and sand filled in; the lever being relieved, the sphere falls by its own weight; the lower flask is removed and the upper flask put on the plate; the sphere is pushed through the plate as before, sand filled in, with great rapidity and accuracy.

The sand covers for filling up that part of the shell which is to be hollow are also carefully and quickly made at Woolwich. The halves of the core-mould open and shut with a lever, so that the bad plan of striking the core-mould is avoided as completely as the bad plan of striking the pattern is in the process of moulding shot and shell.

**Theory of Casting.** Before leaving the subject of the use of sand moulds, we may remark that iron and brass castings with a perfect surface can only be produced when the mould is well dried and heated, so as to drive out any moisture from the apertures between the grains of sand. By this means channels are opened for the rapid escape of the heated air and gas expelled by the entrance of the fluid metal into the mould, and the surface of the metal is not cooled by its contact with damp or cold sand. It is also well to mix charcoal dust, or coke dust, with the sand; and for fine castings to cover the surface of the sand with a coating of charcoal dust. The object of this proceeding is to reduce the oxide which may be present in the metal. This operation of reducing the oxide of a metal instantaneously is performed with the greatest certainty by this simple means, invented, probably, by the earliest metallurgists. By incorporating a quantity of charcoal or coke dust with the sand, or facing the sand with carbonaceous matter, any oxide of the metal which may be floating amongst the pure metal is at once reduced. Sand (being a non-conductor) does not abstract the heat from the fluid metal rapidly, and, therefore, solidification of the metal takes place comparatively regularly and equally throughout the mass; when one part of the casting solidifies before the adjoining part, flaws often occur, and to avoid these the skill of the practical founder is necessary in arranging for the entrance of the metal at the proper point, and for the exit of the air.

We next proceed to the third class of improvements in moulding, that of the extension of the application of metallic moulds.

**Metal Moulds.** The practice of casting bronze weapons in moulds made of bronze (blackened over on their surface to prevent the fluid metal uniting with the mould) appears to have been a very general one among the ancients.

Some moulds of this description have been discovered amongst the Celtic (?) remains disinterred in different parts of Europe.

The facility for the escape of the heated air and gases from the sand moulds into which liquid metal is poured, is so much greater than that from moulds of metal, that at the present time neither brass nor iron is poured into metallic moulds, except when a particular purpose is to be attained, viz., that of chilling the surface of the iron and making it as hard as steel. Iron cannot be chilled or hardened in a sand mould.

**Chilled Iron.** This process of casting in metal moulds was once supposed to be a modern invention; but it now appears, from the metal moulds discovered among the remains of the Celtic race throughout Europe, that the bronze weapons of the people who preceded the Romans were generally cast in metallic moulds, and not in sand. Chilled castings have been brought to great perfection by Messrs. Ramsome, of Ipswich. Their chilled ploughshares and chilled railway chains are cast in moulds of such a construction that the melted iron comes into contact with iron in those parts of the moulds where it is wanted to be chilled. A section of the casting shows the effect of chilling.

**Zinc.** In casting zinc, (a cheap and abundant metal,) which fuses at a low temperature, metallic moulds may be most advantageously used. It is, however, necessary to heat the iron or brass mould nearly to the temperature of melting zinc, in order that the rapid abstraction of heat from the fluid metal may be prevented. The preparation of metal moulds, and the casting soft metal in them, is now an extensive and important industry on the continent, for ornamental zinc castings have suddenly come into extensive use in consequence of the discovery of the electrotyping process. When covered with a thin coating of brass or copper by a galvanic battery, zinc may be bronzed so as to present almost the exact external appearances of real bronze at a tenth of the cost.

When metal moulds are used their first cost is very great, as they must be made in numerous separate pieces so as to liberate the castings. The joints and ornaments have to be chased and accurately fitted at a great expense. Their use, however, requires no skill in the workman, and the rapidity with which the zinc is cast, the mould taken to pieces, and the casting removed, renders the operation a very rapid and economical one. — A. T.
FRANKLINITIE. A somewhat remarkable mineral, which is found at Hamburg, N. J., with red oxide of zinc and garnet in granular limestone. Its composition has been determined to be—

| Oxide of iron  | 66.9 | 65.88 | 66.12 |
| Oxide of manganese | 18.0 | 18.17 | 11.19 |
| Oxide of zinc | 17.9 | 10.81 | 21.77 |

Franklinitie was at first employed for the production of zinc; but for that purpose it did not answer commercially. It is, however, now employed in combination with iron, as it is said, with much advantage. Major Farrington, of New Jersey, thus speaks of it: “Many experiments have been made under my superintendence upon the ore of Franklinitie, and I have also witnessed several others of an interesting character made by other parties in mixing Franklinitie with pig iron in the puddling-furnace, and also a mixture of Franklinitie pig with other irons in their conversion to wrought iron. The result in all cases has been a great improvement in the quality of iron as manufactured. The most marked and, as I consider, the most valuable result is obtained by using from 10 to 15 per cent, of the weight of pig iron to be puddled with pulverized Franklinitie ore in the furnace at each heat. Iron of the most inferior quality, when thus treated, is converted into an article of No. 1 grade. The volatile nature of zinc at a high temperature, combining with the sulphur, phosphorus, and other volatile constituents of the coal, or that may be in the iron, being carried off mechanically, I consider is one of the causes of the improvement; the manganese also of the ore combines with silica at a high temperature, and pig iron that contains silica is thus freed from it. The great advantage to be obtained by using the pulverized ore in the puddling-furnace is, that a high grade of iron may be made; and where reheating has been hitherto deemed indispensable, one heating is found sufficient for such uses as wire billets, nuts, bolts, horseshoe iron, and nails. A particular selection of fuel is not required—coke and charcoal can be dispensed with, and bituminous or anthracite coal used.”

FREEZING. The most intense cold that is as yet known is that from the evaporation of a mixture of solid carbonic acid and sulphuric ether, by which a temperature of 106° Fahr. below the freezing point of water is produced. By means of this intense cold, assisted by mechanical pressure, several of the gaseous bodies have been condensed into liquids, and in some instances solidified.

Sir John Herschel, some years since, recommended the following method for obtaining at moderate cost large quantities of ice:

A steam engine boiler was to be sunk into the earth, and the quantity of water which it was desired to freeze placed in it. By means of a condensing pump, several atmospheres of air were forced into the boiler, and then every thing was allowed to remain for a night, or until the whole had acquired the temperature of the surrounding earth. Then, by opening a stopcock, the air, expanding, escaped with much violence, and the water being robbed of its heat to supply the expanding air, the temperature of the whole was so reduced that a mass of ice was the result.

The following process for producing cold has been patented and exhibited in this country: In a reservoir, or what may with propriety be called a boiler, was placed a quantity of sulphuric ether. This reservoir was placed in a long vessel of saline water, this fluid by the arrangement being made to flow from one end of the trough to the other, that is, to and from the reservoir. In this water was placed a number of vessels the depth and breadth of the trough, but of only two inches in width, and these were filled with the water to be frozen.

A steam engine was employed to pump the air from the reservoir; this being done, of course the ether boiled, and the vapor of the ether was removed by the engine as fast as it was formed. The heat required to vaporize the ether was derived from the saline water in the trough, and this again took the heat from the water in the cells; thus eventually every cell of water was converted into ice. The ether was, after it had passed through the engine, condensed by a refrigeratory of the ordinary kind. The statement made by the patentee was very satisfactory, as it regarded the cost of production. An apparatus of this kind is of course intended for hot countries only, where ice becomes actually one of the necessities of life.

A peculiar physical fact connected with the freezing of water has been made available to some important uses. Water in freezing really rejects everything it may contain—even air, and hence solid ice is actually pure water. This may be easily proved. Make a good freezing mixture, and place some water in a flask, and while it is undergoing consolidation by being placed in the frigorific compound, gently agitate it with a feather. Now, if the water contains spirit, acid, salt, or coloring matter, either of them are allie rejected, and the solid obtained, when washed from the matter adhering to its surface, is absolutely pure solid water.

This philosophic fact, although it has only been subjected to examination within the last few years, has been long known.
FULMINATING SILVER.

The old nobles of Russia, when they desired a more intoxicating drink than usual, placed their wines or spirit in the ice of their frozen rivers, until all the aqueous portion was frozen; when they drank the ardent fluid accumulated in the centre. This plan has been employed also for concentrating lemon juice and the like.

FULMINATING MERCURY, $\text{C}_3\text{H}_5\text{AgNO}_3 + \text{Ag}$, (dried at 212°.) The well-known compound used for priming percussion caps. It was analyzed many years ago by Liebig, and subsequently by Gay-Lussac. Although chemists have long been acquainted with the true composition of fulminic acid, and the formula of fulminating mercury has also been rendered almost certain, no accurate analysis of the latter compound was made public until 1855, when M. Schischkoff published his celebrated paper on the fulminates. It is singular that Liebig and Schischkoff were independently engaged at the same time in investigating the products of decomposition of the fulminates. The formula of fulminic acid, and also that of fulminating mercury, had been deduced from the very accurate analysis of fulminating silver made by Gay-Lussac and Liebig. A great number of processes for the preparation of fulminating mercury have been published. The following are the best as regards economy and certainty:

1. One part of mercury is to be dissolved in 12 parts of nitric acid, of sp. gr. 1.3. To the solution (as soon as it has cooled to 53° F.) 8 parts of alcohol, sp. gr. 0.897, are to be added; the vessel containing the mixture is to be heated in boiling water until thick white fumes begin to form. The whole is then set in a cool place to deposit the crystals of fulminate.—Crommoclod.

2. One part of mercury is to be dissolved in 12 parts of nitric acid, sp. gr. 1.340 to 1.345, in a flask capable of holding 18 times the quantity of fluid used. When the metal is dissolved, the solution is decanted into a second vessel containing 37 parts of alcohol, of 80° to 92°, (Trelles), then immediately poured back into the first vessel, and agitated to promote absorption of the nitrous acid. In five to ten minutes gas bubbles begin to rise, and there is formed at the bottom of the vessel a strongly refracting, specifically heavier liquid, which must be mixed with the rest by gentle agitation. A moment then arrives when the liquid becomes black from separation of metallic mercury, and an extremely violent action is set up, with evolution of a thick white vapor, and traces of nitrous acid; this action must be moderated by gradually pouring in 5-7 parts more of the same alcohol. The blackening then immediately disappears, and crystals of fulminating mercury begin to separate. When the fluid has become cold, all the fulminating mercury is found at the bottom. By this method not a trace of mercury remains in solution.—Liebig.

The fulminate in all these processes is to be collected on filters, washed with distilled water, and dried. The violent reaction which takes place when the solution of mercury reacts on the alcohol, is essential to the success of the operation.

With regard to the economy of the above methods, it has been found that 1 part of mercury yields the following proportions of fulminate:

1st process, 1:25
2d " " 1:53

FULMINATING SILVER, $\text{C}_3\text{AgN}_2\text{O}_7$. This salt corresponds in constitution to the fulminate of mercury; it may also be prepared by analogous processes, merely substituting silver for mercury. Preparation.—1. 1 part of silver is to be dissolved in 24 parts of nitric acid, sp. gr. 1.5, previously mixed with an equal weight of water. To the solution is to be added alcohol equal in weight to nitric acid. Produce, 1.5 parts of fulminating silver. 2. 1 part of silver is to be dissolved in 20 parts of nitric acid, sp. gr. 1.38. To the solution is to be added 27 parts of alcohol, sp. gr. 0.882. The mixture is to be heated to boiling, and as soon as it shows signs of becoming turbid, it is to be removed from the fire, and a quantity of alcohol, equal in weight to the first, is to be poured in. The liquid is now to be allowed to become perfectly cold, when the fulminate will be found at the bottom of the vessel. Produce, equal to the silver employed. 3. 1 part of silver is to be dissolved in ten times its weight of nitric acid, sp. gr. 1.36. To the solution is to be added 30 parts of alcohol, sp. gr. 0.83. The mixture is to be treated as in the second mode of preparation, except that no more alcohol is to be added. The produce should be in fine crystals. Whichever mode of preparation be selected, it is absolutely necessary, in order to avoid fearful accidents, that the following precautions be attended to: The beakers or flasks employed must be two or three times larger than is required to hold the ingredients, for it is owing to frothing or boiling over, any of the fluid happened to find its way to the outside, and dry there, an explosion might ensue. Care must also be taken that the highly inflammable vapors given off during the preparation do not come near any flame. The salt, when formed, must be received on a filter, and well washed with cold water. It is safer to dry it slowly than in the oven; for although it will endure a heat above that of boiling water before exploding, yet when warm, the slightest touch with a hard substance is often sufficient to cause a terrible detonation. A spatted of pasteboard or very thin wood should be employed to transfer it into its receptacle. Fulminating silver should not be kept in
FUR.

glass vessels, for fear of the salt finding its way between the cork or stopper, the slightest movement with a view of opening the vessel, being then sufficient to cause an accident. Small paper boxes are the safest to keep it in.

Fulminating silver gives a more violent detonation than the corresponding mercurial compound. The presence of roughness or granular particles on the substances with which it may be in contact, assists greatly in causing it to explode.

Although giving so violent an explosion when alone, it may be burnt without danger when mixed with a large excess of oxide of copper, as in the ordinary process of organic analysis. It then gives off a mixture of two volumes of carbonic acid, and one volume of nitrogen.

Gay-Lussac and Liebig made an analysis of the sift in this manner, with the annexed results:

<table>
<thead>
<tr>
<th></th>
<th>Experiment</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>7.0</td>
<td>24</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>9.2</td>
<td>28</td>
</tr>
<tr>
<td>Silver</td>
<td>72.2</td>
<td>216</td>
</tr>
<tr>
<td>Oxygen</td>
<td>10.7</td>
<td>32</td>
</tr>
</tbody>
</table>

Total 100.0

For further remarks on the fulminating, see FULMINATING MERCURY.—C. G. W.

FUR. Furs are subject to injury by several species of moths, whose instinct leads them to deposit their eggs at the roots of the fine hair of animals.

Linnæus mentions five species that prey upon cloth and furs, of which *Tinea pellionella*, *T. rusticella* and *T. tapa* are the most destructive. No sooner is the worm hatched than it eats its path through the fur, and continues increasingly destructive until it arrives at its full growth, and forms itself a silken covering, from which, in a short time, it again emerges a perfect moth.

Another cause of the decay of fur is the moisture to which they are frequently exposed; the delicate structure of the fine under fur cannot be preserved when any dampness is allowed to remain in the skin. This fact is well known to the leather manufacturer, who, having wetted his skins, allows them to remain in a damp cellar for a few days, for the purpose of removing the hair, which is pulled out with the greatest facility, after remaining only one week in a moist condition. It follows from these observations, that to preserve the fur it is necessary to keep them dry, and to protect them from moths; if exposed to rain or damp, they must be dried at a moderate distance from the fire; and when put by for the summer should be combed and beaten with a small cane, and very carefully secured in a dry brown paper or box, into which moths cannot enter. During the summer they should be examined once a month to be again beaten and dried, if the situation in which they have been placed be at all damp. With these precautions, the most valuable furs may be preserved uninjured for many years.

FUEL. During the distillation of corn or grape spirits there is always separated a fiery foetid oil of nauseous odor and taste. This is the substance which is the cause of the unpleasant effects which are produced upon most persons by even a small quantity of insufficiently rectified whiskey or brandy. Any spirit which produces milkiness on the addition of four or five times its volume of water, may be suspected to contain it. By repeated rectification every trace may be removed.

Fusel oil invariably consists of one or more homologues of the vinic alcohol, (CH₃PO₃), mixed with variable quantities of the latter substance and water. The nature of fusel oil varies much with the source from whence it is obtained. That which is ordinarily sold in this country for the purpose of yielding pear essence consists mainly of the amyllic alcohol, (CH₃PO₃), mixed with one-fourth to one-fifth of spirit of wine.

The progress of organic chemistry has been greatly assisted by the researches which have been made upon fusel oil, almost all the amyllic compounds hitherto obtained having been directly or indirectly obtained from it.

To obtain fusel oil in a state of purity it is necessary, in the first place, to rectify it fractionally. By this means it will be found that much alcohol can be removed at once. If a great quantity of water and very little vinic alcohol be present, the simplest mode of purification is to shake it with water, by which means common alcohol is removed in solution, while the amyllic alcohol, owing to its comparative insusceptibility, may be easily separated by the tap-funnel. After drying over chlorid of calcium, it is to be again rectified once or twice, only that portion distilling at about 269°6 Fahr. (182° Cent.) being received. The product of this operation is pure amyllic alcohol, from which an immense number of derivatives of the amyllic series can be obtained. By treatment with sulphuric acid and bichromate of potash it is converted into valeric acid. In this manner all the valeric acid now so much employed in medicine is prepared. By distilling amyllic alcohol with sulphuric acid and acetic acid of potash, we obtain the acetate of amyle, commercially known as jargonelle pear essence.

The foreign fusel oils obtained from the grape marc contain several homologues higher.
and lower in the series than the amyllic alcohol. In fact, it would appear that during the fermentation of grapes there are formed, not only alcohols, but ethers and acids.

M. Chancel, by repeatedly rectifying the dehydrated and more volatile portions of the residues of the distillation of grape marc alcohol, succeeded in isolating a fluid boiling at 205° Fahr. This proved to be pure propionic alcohol. M. Wurtz has also been able to obtain the butylc alcohol by rectifying certain specimens of potato oil.

All fusel oils are not so complex. The author of this article has repeatedly examined specimens of English and Scotch fusel oil, which did not contain anything save the ethylc and amyllic alcohols, accompanied by small portions of the acids, which are procured by their oxidation. M. Chancel has given the following equations, which explain the manner in which saccharine matters break up into homologous alcohols under the influence of fermentations. I have reduced the unitary notation employed by him into the ordinary formula used in this country, in order to render the relations as clear as possible to the reader.

\[
\begin{align*}
2C_2H_4O_2 & = 8CO_2 + 4C_2H_4O_2. \\
\text{Glucose} & \quad \text{Alcohol.} \\
2C_2H_4O_2 & = 8CO_2 + C_4H_6O_2 + 2C_2H_2O_2 + 2H_2O. \\
\text{Propionic alcohol.} \\
2C_3H_6O_2 & = 8CO_2 + 2C_2H_4O_2 + 4H_2O. \\
\text{Butylc alcohol.} \\
2C_4H_8O_2 & = 8CO_2 + C_4H_6O_2 + 2C_2H_2O_2 + 4H_2O. \\
\text{Amylic alcohol.}
\end{align*}
\]

M. Chancel appears to consider the last equation as indicating the necessity of propionic alcohol being always formed wherever amyllic alcohol is generated; but this is not in accordance with the results of those chemists who have examined crude amyllic alcohol repeatedly for propionic alcohol, but without finding any. The formation of these interesting homologues appears therefore to depend upon special circumstances connected with the fermentation.

The capricc alcohol is also contained in certain varieties of fusel oil.

Fusel oil has been patented as a solvent for quinine, but its odor, and more especially that produced by its oxidation, so persistently adheres to any thing with which it has been in contact, that great care is requisite in the purification. It is remarkable that at the first instant of smelling most specimens of fusel oil, the odor is not unpleasant, but in a very few seconds it becomes exceedingly repulsive, and provokes coughing.—G. G. W.

GALVANIZED IRON. This is the name, improperly given, first in France, and subsequently adopted in this country, to iron coated with zinc by a peculiar patent process.

In 1887, Mr. H. W. Crawfurd patented a process for zincing iron. In the "Reperotory of Patent Inventions" his process is thus described: Sheet iron, iron castings, and various other objects in iron, are cleaned and scoured by immersion in a bath of water, acidulated with sulphuric acid, heated in a leaden vessel, or used cold in one of wood, just to remove the oxide. They are then thrown into cold water, and taken out one at a time to be scoured with sand and water with a piece of cork, or more usually with a piece of the husk of the cocoanut, the ends of the filaves of which serve as a brush, and the plates are afterwards thrown into cold water.

Pure zinc covered with a thick layer of sal ammoniac is then melted in a bath, and the iron, if in sheets, is dipped several sheets at a time in a cradle or grating. The sheets are slowly raised to allow the superfluous zinc to drain off, and are thrown whilst hot into cold water, on removal from which they only require to be wiped dry.

Thick pieces are heated, before immersion, in a reverberatory furnace, to avoid cooling the zinc. Chains are similarly treated, and on removal from the zinc require to be shaken until cold, to avoid the links being soldered together. Nails and small articles are dipped in muriatic acid, and dried in a reverberatory furnace, and then thrown all together in the zinc, covered with the sal ammoniac, left for one minute, and taken out slowly with an iron skimmer. They come out in a mass, soldered together, and for their separation are afterwards placed in a crucible and surrounded with charcoal powder, then heated to redness and shaken about until cold, for their separation. Wire is reeled through the zinc, unto which it is compelled to dip by a fork or other contrivance. It will be understood that the zinc is melted with a thick coat of sal ammoniac to prevent the loss of zinc by oxidation.
The plates are immersed in a cleansing bath of equal parts of sulphuric or muriatic acid and water, used warm; the works are then milled and scrubbed with emery and sand to detach the scales, and to thoroughly clean them; they are then immersed in a "preparing bath" of equal parts of saturated solutions of muriate of zinc and sal ammoniac, from which the works are transferred to a fluid metallic bath, consisting of 202 parts of mercuric and 1,292 parts of zinc, both by weight, to every ton weight of which alloy is added above one pound of either potassium or sodium, the latter being preferred. As soon as the cleaned iron works have attained the melting heat of the triple alloy, they are removed, having become thoroughly coated with zinc. At the proper fusing temperature of this alloy, which is about 650° Fahr., it will dissolve a plate of wrought iron of an eighth of an inch thick in a few seconds.

Morewood and Rogers' galvanized tinned iron is prepared under several patents. Their process is as follows:

The sheets are pickled, scoured, and cleaned, just the same as for ordinary tinning. A large wooden bath is then half filled with a dilute solution of muriate of tin, prepared by dissolving metallic tin in concentrated muriatic acid, which requires a period of two or three days. Two quarts of the saturated solution are added to 300 or 400 gallons of the water contained in the bath. Over the bottom of the bath is first spread a thin layer of finely-granulated zinc, then a cleaned iron plate, and so on, a layer of granulated zinc and a cleaned iron plate alternately, until the bath is full. The zinc and iron, together with the fluid, constitute a weak galvanic battery, and the tin is deposited from the solution so as to coat the iron with a dull uniform layer of metallic tin in about two hours.

The tinned iron is then passed through a bath containing fluid zinc, covered with sal ammoniac mixed with earthy matter, to lessen the volatilization of the sal ammoniac, which becomes as fluid as treacle. Two iron rollers immersed below the surface of the zinc, are fixed to the bath and are driven by machinery to carry the plates through the fluid metal at any velocity previously determined. The plates are received one by one from the tinning bath, drained for a short time, and passed at once, whilst still wet, by means of the rollers, through the bath as described. The plates take up a very regular and smooth layer of zinc, which, owing to the presence of the tin beneath, assumes its natural crystalline character, giving the plates an appearance resembling that known as the mètallique.

It is stated that galvanized iron plates, cut with shears so as to expose the central iron, become zinced round the edges, and at the holes where the nails were driven. We are also informed that ungalvanized iron will, if moist when near galvanized plate, become zinced, and that telegraph wires, where cut through, become coated by the action of the rain water on the galvanized portion of the surfaces.

It has been stated that the galvanized iron is not more durable than unprotected iron; that, indeed, where the zinc is by any accident removed, the destruction is more rapid than ordinary. We have made especial inquiries, and find that in forges where there is any escape of sulphur vapor the galvanized iron does not stand well, but that under all ordinary circumstances it has the merit of great durability in addition to its other good qualities.

GARNET. (Grenat, Fr.) Garnet is a silicate of some base, which may be lime, magnesia, oxide of iron, &c.

There are six sub-species of garnet, viz.:
I. Alumina-lime garnet, consisting of the silicates of alumina and lime.
II. Alumina-magnesia garnet, consisting of the silicates of alumina and magnesia.
III. Alumina-iron garnet, consisting of the silicates of alumina and iron.
IV. Alumina-manganese garnet, consisting of the silicates of alumina and manganese.
V. Iron-lime garnet, consisting of the silicates of iron and lime.
VI. Lime-chrome garnet, consisting of the silicates of lime and oxide of chromium.

I. Lime-garnet, or grossular, is composed of silica, 40.1; alumina, 22.7; lime, 37.2 = 100.0. Color, pale greenish, clear red, and reddish orange, cinnamon color. Before the blowpipe, fuses to a slightly greenish glass or cermel; soluble, when powdered, in concentrated muriatic acid.

This section comprises cinnamon-stone or Essonite, grossular or Wiluite, Romanzovite, topazolite, and succinite.

II. Magnesia-garnet is of a deep coal-black color, with a resinous lustre. The variety from Arendal is composed of silica, 43.45; alumina, 22.47; protoxide of iron, 9.29; protoxide of manganese, 6.27; magnesia, 13.43; lime, 6.53 = 100.44.—(Wächtmeister.) Before the blowpipe, easily fusible, forming with luminescence a dark grayish-green globule, which is non-magnetic.

III. Iron-garnet comprises the almandine or precious garnet, allochroite, and common garnet. It is composed of silica, 56.5; alumina, 20.5; protoxide of iron, 43.2 = 100.0. Before the blowpipe, fuses rather easily, with an iron reaction.

IV. Manganese-garnet, or spezzartine, is of a brownish-red color, and is composed of.
GEMS, ARTIFICIAL.

sili
c, 55.83; alumina, 18.06; protoxide of iron, 14.93; protoxide of manganese, 30.96 = 99.78. (Analysis of M. garnet from Haddam, U. S., by Seghert.) Before the blowpipe, gives a manganese reaction.

V. Iron-lime garnet includes aplone, colophonite, melanite, and pyreneite. These vary in color from dark red, brownish black, to black, and possess a shining lustre, which is sometimes resinosus, as in colophonite.

Analysis of the aplone of Altencau:—Silica, 35.64; lime, 29.22; protoxide of iron, 30.00; protoxide of manganese, 3.01; potash, 2.35 = 100.22.—Wächmeister.

VI. Lime-chrome garnet, or ouvarovite, is of an emerald-green color. Sp. gr., 3.418. Before the blowpipe it is infusible alone, but with borax affords a chrome-green glass. It occurs at Biserak, in Russia.

Analysis by Erdmann:—Silica, 38.93; alumina, 5.98; peroxide of iron, 19.6; oxide of chrome, 21.84; magnesia, 1.54; carbonate of lime, 31.06; oxide of copper, a trace = 99.58.

The garnet varies greatly in transparency, fracture, and color; but when the colors are rich, and the stone is free from flaws, it constitutes a valuable gem, which may be distinguished by the following properties:

The color should be blood or cherry-red; on the one hand often mixed more or less with blue, so as to present various shades of crimson, purple, and reddish violet, and on the other hand, with yellow, so as to form orange red and lycanthine brown.

The stones vary in size from the smallest pieces that can be worked to the size of a nut. When above that size they are scarcely ever free from flaws, or sufficiently transparent for the purposes of the jeweller.

The garnets of commerce are procured from Bohemia, Ceylon, Pegu, and the Brazils. By jewellers they are classed as Syrian, Bohemian, or Cingalese, rather from their relative value and fineness, than with any reference to the country from which they are supposed to have been brought.

Most esteemed are called Syrian garnets, not because they come from Syria, but after Syrian, the capital of Pegu, which city was formerly the chief mart for the finest garnets. The color of the Syrian garnet is violet-purple, which, in some rare instances, vies with that of the finest oriental amethyst; but it may be distinguished from the latter by acquiring an orange tinge by candle-light. The Syrian garnet may be also distinguished from all the other varieties of garnet in preserving its color (even when of considerable thickness and unpolished by fail) mantled with the black tint which usually obscures this gem. The Bohemian garnet is generally of a dull poppy-red color, with a very perceptible lycanthine-orange tint when held between the eye and the light. When the color is a full crimson it is called pyrope, or fire-garnet—a stone of considerable value when perfect and of large size.

The best manner of cutting the pyrope is en cabochon, with one or two rows of small facets round the girdle of the stone. The color appears more or less black when the stone is cut in steps, but when cut en cabochon, the points on which the light falls display a brilliant fire-red.

Garnet is easily worked, and when facet-cut is nearly always (on account of the depth of its color) formed into thin tables, which are sometimes concave or hollowed out on the under side. Cut stones of this latter description, when skilfully set, with a bright silver foil, have often been sold as rubies.

The garnet may be distinguished from corundum or spinel by its duller color. Coarse garnets reduced to a fine powder are sometimes used as a substitute for emery in polishing metals.—H. W. B.

GAS PIPES. In the present method of manufacturing the patent welded tube, the end of the skelp is bent to the circular form, its entire length is raised to the welding heat in an appropriate furnace, and as it leaves the furnace almost at the point of fusion it is dragged by the chain of a draw-bench, after the manner of wire, through a pair of tongs with two bell-mouthed jaws. These are opened at the moment of introducing the end of the skelp, which is welded without the agency of a mandrel.

By this ingenious arrangement wrought-iron tubes may be made from the diameter of six inches internally, and about one-eighth to three-eighths of an inch thick, to as small as one-quarter inch diameter and one-tenth bore; and so admirably is the joining effected in those of the best description that they will withstand the greatest pressures of gas, steam, or water to which they have been subjected, and they admit of being bent, both in the heated and cold state, almost with impunity. Sometimes the tubes are made one upon the other, when greater thickness is required, but these stout pipes and those larger than three inches are comparatively but little used.—(Holtszappel.)

GEMS, ARTIFICIAL. These are glasses, the material of which they are composed being called Strass. 

Strass, the paste or glass which generally forms the principal ingredient of imitation gems, is called after the name of a German jeweller, by whom it was invented, at the com-

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GEMS, ARTIFICIAL.

mencement of the last century. It is composed of silica, potash, borax, the various oxides of lead, and sometimes of arsenic; chemically it may be regarded as a double silicate of potash and lead.

The silica may be furnished either by rock crystal, white sand, or flint; but of these the first is to be preferred, one of the principal considerations in these preparations being the extreme purity of the materials or ingredients employed. In this manufacture, which is of more importance and attended with greater difficulty than most persons imagine, perfect success (independently of the choice of materials) depends upon the care taken, and the precautions to be observed. No crucibles should be used but those which have been proved, both as regards their composition, their power of withstanding the strongest heat, and their impenetrability to the action of metallic oxides.

All the substances to be melted should be first pulverized, and even ground with the greatest care. It should be remembered that the most perfect mixture can only be effected by numerous siftings, and that a separate sieve should be used for each ingredient, and never be made to serve for different substances. When mixed, the materials should be melted in a crucible placed in the middle of a cylindrical furnace terminated in a dome, the height of which should be 7 feet 6 inches, and its diameter 4 feet 6 inches. The fuel should consist as much as possible of thoroughly dry wood, chopped very small. The melting should be effected by means of a heat raised by degrees, and then steadily maintained, especially at the maximum temperature; then, when once the melting has been thoroughly accomplished, which cannot be in less than from twenty to thirty hours, the crucible must be allowed to cool very slowly.

The art of imitating precious stones in paste has amazingly improved since the time of Strass, as was shown by the results of the great Paris exhibition of 1855. The imitations, especially as regards certain colors, leave little to be desired; but there is something still in that respect in which the imitation is far from being perfect.

Now that it is proved that the alkalies and vitrifiable earths are oxides of the metals, all that has to be done to obtain the finest effects, is to combine them skilfully, and in their present forms, with other artificially prepared metallic oxides which have undergone the process of vitrification.

Experiments ought to be made with all oxidizable and vitrifiable substances, with the different salts, fluors, phosphates, phosphoric acid, &c.

The following are some of the mixtures generally known, but it must be observed here that each artist has his own processes, ingredients, and proportions.

**Common Strass.**

Litharge, 77·16; white sand, 57·75; potash, 7·71.

**Strass of Douhants-Wieland.**

| Sifted rock crystal | 2897·5 | Deutoxide of arsenic | 492 |
| Boraie acid | 181·18 | Potash (purer) | 1608·53 |
| Minium (purer) | 4151·37 |

**English Strass.**

| Calcined flints | 902·5 | Calcined borax | 361·9 |
| Pure potash | 481·25 | Fine white lead | 120·89 |

**Strass Bastenaire.**

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<thead>
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<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
</tr>
</thead>
<tbody>
<tr>
<td>White sand treated with hydrochloric acid</td>
<td>Grains</td>
<td>Grains</td>
<td>Grains</td>
<td>Grains</td>
</tr>
<tr>
<td>1548·23</td>
<td>1548·23</td>
<td>885·8</td>
<td>385·8</td>
<td>385·8</td>
</tr>
<tr>
<td>Minium, first quality</td>
<td>6·16</td>
<td>2156·1</td>
<td>771·61</td>
<td>925·8</td>
</tr>
<tr>
<td>White potash, well calcined</td>
<td>370·32</td>
<td>489·76</td>
<td>108·24</td>
<td>61·72</td>
</tr>
<tr>
<td>Calcined borax</td>
<td>308·64</td>
<td>185·16</td>
<td>92·66</td>
<td>125·45</td>
</tr>
<tr>
<td>Crystallized nitrate of potash (ultra)</td>
<td>185·16</td>
<td>123·44</td>
<td></td>
<td>77·16</td>
</tr>
<tr>
<td>Peroxide of manganese</td>
<td>61·72</td>
<td>92·66</td>
<td>154·32</td>
<td></td>
</tr>
<tr>
<td>Deutoxide of arsenic</td>
<td></td>
<td>92·66</td>
<td>23·15</td>
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**Varyingly Colored Strass.**

**Topaz:** No. 1.

Whitest strass, 842·079; glass of antimony, 36·421; purple of Cassius, 0·788.

**Another.**

White lead of Clichy, 771·6; flints calcined and pulverized, 771·6.
GEMS, ARTIFICIAL.

Another.

White sand, well dressed - 1543-23 Oxide of silver - - 77-16
Borax, calcined - - 138-88 Calcined potash - - 432-75
Mineral - - 2257-64


Emerald, No. 1. Strass, 3858-087; pure green oxide of copper, 35-643; oxide of chrome, 1-697.

Ditto: ordinary. Strass, 7716-174; acetate of copper, 61-11; oxide of iron, 12-731.

Stass: another. Strass, 481-25; oxide of copper precipitated from the nitrate by potash, 324-45.

EMERALDS (Bastenaire.)

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<tr>
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<tbody>
<tr>
<td></td>
<td>Grains.</td>
<td>Grains.</td>
</tr>
<tr>
<td>Well washed sand</td>
<td>154-32</td>
<td>154-32</td>
</tr>
<tr>
<td>Minum</td>
<td>231-48</td>
<td>231-48</td>
</tr>
<tr>
<td>White potash, calcined</td>
<td>46-29</td>
<td>77-16</td>
</tr>
<tr>
<td>Borax, calcined</td>
<td>39-86</td>
<td>30-86</td>
</tr>
<tr>
<td>Yellow oxide of antimony</td>
<td>7-71</td>
<td>-</td>
</tr>
<tr>
<td>Pure oxide of cobalt</td>
<td>1-54</td>
<td>-</td>
</tr>
<tr>
<td>Green oxide of chrome</td>
<td>385</td>
<td>-</td>
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AMETHYST (Bastenaire.)

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<tr>
<td></td>
<td>Grains.</td>
<td>Grains.</td>
</tr>
<tr>
<td>Strass</td>
<td>7716-17</td>
<td>3858-087</td>
</tr>
<tr>
<td>Oxide of manganese</td>
<td>20-39</td>
<td>36-55</td>
</tr>
<tr>
<td>Oxide of cobalt</td>
<td>0-848</td>
<td>20-39</td>
</tr>
<tr>
<td>Purple of Cassius</td>
<td>-</td>
<td>0-848</td>
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Aquamarine.

Strass, 2918-30; glass of antimony, 20-370; oxide of cobalt, 1-265.

Syrian Garnet.

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<tr>
<td></td>
<td>Grains.</td>
<td>Grains.</td>
</tr>
<tr>
<td>Strass</td>
<td>427-931</td>
<td>484-25</td>
</tr>
<tr>
<td>Glass of antimony</td>
<td>218-815</td>
<td>-</td>
</tr>
<tr>
<td>Purple of Cassius</td>
<td>1-607</td>
<td>2-150</td>
</tr>
<tr>
<td>Oxide of manganese</td>
<td>1-607</td>
<td>-</td>
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Observations.—For topaz, No. 1, the clearest and most transparent glass of antimony should be used. Frequently this mixture only yields an opaque mass, translucent on the edges, and transmitting in thin fragments a red color when held between the eye and the light; in that case rubies may be made of it.

To make them, a portion of the topaz material is taken, and mixed with eight parts of fine strass; these are melted in a Hessian crucible for thirty hours in a potter's furnace, and the result is a beautiful yellow glass-like strass, which, when cut, produces an imitation of the finest oriental rubies.

These may be made of another tint by using the following proportions:

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<tr>
<td>Strass, 2411-25; oxide of manganese, 61-210.</td>
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In the emerald, No. 1, by increasing the proportion of chrome or oxide of copper, and mixing with it oxide of iron, the green shade may be varied, and the peridot or deep-tinted emerald may be imitated.

The manufacture of artificial gems has acquired an extreme development; immense factories are established at Septmoneal in the Jura, furnishing employment to more than 100 work-people, who produce fabulous quantities.

Many ingenious persons in Paris vie with one another in bringing to perfection the most perfect processes, and produce truly surprising results. M. Savary especially, in his mag-
GERMAN SILVER.

nificent collections, and his perfect imitation of celebrated diamonds, has arrived at a degree of excellence which, apparently, can scarcely be surpassed.

We have alluded only to those imitations of gems in glass of which a large portion of the cheap jewellery is formed. Some very successful attempts have been made to manufacture true gems by an artificial process. M. Edelmen has done much in this direction, and M. Henri Sainte-Chire Deville and M. Henri Caron communicated to the Academy of Sciences of Paris, in April, 1858, a process which they had discovered for the production of a number of the gems which belong to the corundum class, as the ruby, sapphire, &c.

Essentially, the process consisted in exposing the fluoride of aluminium, mixed with a little charcoal and boracic acid, in a black lead crucible, protected from the action of the air, to a white heat for about an hour.

For details of the process see Comptes Rendus, Annales de Chimie.

GERMAN SILVER. See Alloy and Copper. M. Gersdorf, of Vienna, states that the proportion of the metals in this alloy should vary according to the use for which it is destined.

When intended as a substitute for silver, it should be composed of 25 parts of nickel, 25 of zinc, and 50 of copper. An alloy better adapted for rolling consists of 25 of nickel, 20 of zinc, and 60 of copper. Castings, such as candlesticks, bells, &c., may be made of an alloy consisting of 20 of nickel, 20 of zinc, and 60 of copper, to which 5 of lead are added. The addition of 2 or 3 of iron (in the shape of tin plate) renders the alloys much whiter, but at the same time harder and more brittle.

Korostein has given the following analysis of the genuine German silver, as made from the original ore found in Hildburghausen, near Sudh, in Hesseberg:

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<tbody>
<tr>
<td>Copper</td>
<td>40.4</td>
</tr>
<tr>
<td>Nickel</td>
<td></td>
</tr>
<tr>
<td>Zine</td>
<td>25.6</td>
</tr>
<tr>
<td>Iron</td>
<td>2.6</td>
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100.0

Chinese paktong, a white alloy, according to the same authority, consists of 5 parts of copper alloyed with 7 parts of nickel and 7 parts of zinc.

The best alloy for making bearings, bushes, and steps for the steel or iron gudgeons and pivots of machinery to run in, is said to consist of 90 parts of copper, 5 of zinc, and 5 of antimony.

GLASS. Bohemian glass.—M. Peligot states that the hard glass of Bohemia is composed of 100 parts of silica, 12 parts of quicklime, and only 28 parts of carbonate of potash. These proportions give a glass quite unmanageable in ordinary furnaces; but the addition of a comparatively small quantity of boracic acid is capable of determining fusion, and the result is a glass having all the requisite limpidity at a high temperature, and possessing at the same time a great brilliancy and hardness.

The Bohemian glass is, within certain limits, perfectly elastic, and very sonorous; when well made, it is sufficiently hard to stand fire with steel, and is scratched with difficulty. The lead glasses, on the other hand, have but little hardness, and less in proportion as they contain more oxide of lead; besides which, they rapidly lose their brilliancy by use.

The silica which is employed in Bohemia in the manufacture of glass, is obtained by calcining crystalline quartz, and afterwards pounding it while dry. When the quartz has been heated to a cherry red, it is withdrawn from the fire, and thrown immediately into cold water.

Almost all the Bohemian glass is a potash glass, because soda and its salts give to glass a sensible yellowish tint. The limestone which is used is as white as Carrara marble. The clay employed for the crucibles is very white, and consists of silica, 48.8; alumina, 40.4; and water, 13.8.

The manufacture of glass in Bohemia is of very high antiquity, and the same peculiarities have always belonged to the true Bohemian manufacture.

In our modern times the Bohemian glass has been more especially celebrated for the beautiful varieties of colors which are produced. See Glass, colored.

Venetian glass.—From an early date the city of Venice has been celebrated for its glass; the reticulated glass, the crackle glass, and the glass paper-weights, or millefiore, are all due to the Venetians.

The manufacture of glass beads at Murano, near Venice, has been carried on for an indefinite period, and Africa and Asia have been supplied from their glass-houses. The process is most ingeniously simple. Tubes of glass, of every color, are drawn out to great lengths in a gallery adjoining the glass-house pots, in the same way as the more moderate lengths of thermometer and barometer tubes are drawn in our glass-houses. These tubes are chopped into very small pieces of nearly uniform length on the upright edge of a fixed chisel. These elementary cylinders being then put in a heap into a mixture of fine sand and wood ashes, are stirred about with an iron spatula till their cavities get filled. This curvaceous mixture is now transferred to an iron pan suspended over a moderate fire, and con-
GLASS, COLORED.

Finally stirred about as before, whereby the cylindrical bits assume a smooth rounded form, so that when removed from the fire and cleared out in the bore they constitute beads, which are packed in cases, and exported in prodigious quantities to almost every country. See Gems, Artificial.

The manufacture of reticulated glass, for which Venice was equally celebrated, was long lost; it was at length revived by Pohl, and the crucible glass was in like manner reproduced by Mr. Apsey Pellatt in 1851.

The reticulated glass is produced by a kind of network consisting of small bubbles of air inclosed within the mass, and ranged in regular series crossing and intersecting each other. To produce this ornamental appearance, hollow glass cones or conical tubes are kept prepared, containing already this network arrangement of air bubbles. These tubes are made by arranging a number of small glass rods round a centre, so as to form a cylinder, and fixing them in this position by melted glass. The cylinder is then heated until the single rods stick together, when they are drawn out on the pipe to a long cone, and spirally twisted at the same time, the one half to the right and the other to the left, when one of these hollow cones is inserted in the other, and the two are heated until they fuse together; wherever the little rods cross each other a bubble of air will be inclosed, and this occurring in a very regular manner, the reticulated appearance is produced. The Venetians were also celebrated for their "filigree." This glass has of late years been reintroduced in France and in this country. The process of manufacture has been thus described by Mr. Apsey Pellatt, in his Curiosities of Glass Manufacture:

"Before ornaments or vessels can be blown, small filigree canes, with white or variously colored enamels, must be drawn. These are first 'whetted' off the required lengths, and then put into a cylindrical mould with suitable internal recesses, and both cane and mould are thus submitted to a moderate heat. The selection of the color of the canes depends upon the taste of the manufacturer: two to four white enamel canes are chiefly used, alternately, with about half the number of colored. The blower then prepares a solid ball of transparent flint glass, which being deposited in contact with the various canes, at a welding heat, occasions them to adhere. This solid ball is then taken from the mould, is reheated, and 'marersed' till the adhering projecting ornamental canes are rubbed into one uniform mass; the ball is next covered with a gathering of white glass, which must then be drawn to any size and length that may be required. Should a spiral cane be preferred, the 'pucellas' holds the apex in a fixed position, while the ornamental mass, still adhering to the glass-maker's iron, is revolved during the process, till the requisite twist is given. Where vases are formed of alternately colored and enamelled filigree canes, the above process is repeated, and the usual mode of blowing is followed."

The Venetian ball is a collection of waste pieces of filigree glass conglomerated together without regular design; this is packed into a pocket of transparent glass, which is adhesively collapsed upon the interior mass by sucking up, producing outward pressure of the atmosphere.

Midstof, or star work of the Venetians, is similar to the last, only the lozenges of glass are more regularly placed.

The Vitro di Trino of the Venetians is similar to the filigree in many respects; but by closing an outer on the inner case, each containing filigree canes, a bubble of air is inclosed between each crossing of the canes.

The celebrated frosted glass of the Venetians was reintroduced by Mr. Apsey Pellatt, in 1831, who thus describes the process of manufacture: "Frosted glass, like Vitro di Trin, is one of the few specimens of Venetian work not previously made by the Egyptians and the Romans, and not since executed by the Bohemian or French glass-makers. The process of making it, until recently practised at the Falcon Glass Works, was considered a lost art. Frosted glass has irregularly varied marble-like projecting dislocations in its intervening fissures. Suddenly plunging hot glass into cold water, produces crystalline convex fractures, with a polished exterior, like Derbyshire spar; but the concave intervening figures are caused, first by chilling, and then reheating at the furnace and simultaneously expanding the reheated ball of glass by blowing, thus separating the crystals from each other, and leaving open figures between, which is done preparatory to forming vases or ornaments. Although frosted glass appears covered with fractures, it is perfectly sonorous."

GLASS, COLORED. Most of the metallic oxides impart a color to glass, and some non-metallic, and even some substances derived from the organic kingdom have the power of imparting permanent colors to the vitreous combinations of flint and potash. There is much in this subject which still requires examination. M. Bontems, at the meeting of the British Association at Birmingham, brought forward some very extraordinary facts in connection with the coloring powers of different bodies. Of his communication the following is an abstract:

In the first place it was shown that all the colors of the prismatic spectrum might be given to glass by the use of the oxide of iron in varying proportions, and by the agency of different degrees of heat; the conclusion of the author being, that all the colors are pro-
GLASS, COLORED.

duced in their natural disposition in proportion as you increase the temperature. Similar phenomena were observed with the oxide of manganese. Manganese is employed to give a pink or purple tint to glass, and also to neutralize the slight green given by iron and carbon to glass in its manufacture. If the glass colored by manganese remains too long in the melting-pot or the annealing-kiln, the purple tint turns first to a light brownish red, then to yellow, and afterwards to green. White glass in which a small proportion of manganese has been used, is liable to become light yellow by exposure to luminous power. This oxide is also, in certain window glass, disposed to turn pink or purple under the action of the sun's rays. M. Bontemps has found that similar changes take place in the annealing-oven. He has determined, by experiments made by him on polygonal lenses for M. Fresnel, that light is the agent producing the change mentioned; and the author expresses a doubt whether any change in the oxidation of the metal will explain the photogenic effect. A series of chromatic changes of a similar character were observed with the oxides of copper, the colors being in like manner regulated by the heat to which the glass was exposed. It was found that silver, although with less intensity, exhibited the same phenomena; and gold, although usually employed for the purpose of imparting varieties of red, was found by varying degrees of heating at a high temperature, and recasting several times, to give a great many tints, varying from blue to pink, red, opaque yellow, and green. Charcoal in excess in a mixture of silica-alkaline glass gives a yellow color, which is not so bright as the yellow from silver; and this yellow color may be tarnished to a dark red by a second fire. The author is disposed to refer these chromatic changes to some modifications of the composing particles, rather than to any chemical changes in the materials employed.

It is not possible in the present essay to enter into the minute details of this beautiful branch of glass manufacture. In the following statement the materials ordinarily employed to color glass alone are named:

Yellow. Charcoal or soot is used for producing the commoner varieties of yellow glass.

The glass of antimony, which is obtained by roasting sulphide of antimony until antimonial acid is formed, and melting it with about 5 per cent. of undecomposed sulphide of the same metal.

The antimoniate of potash, a preparation similar to James's powder, is stated to answer the same purpose. Bohemian glass is colored yellow with glass of antimony, mumium, and oxide of iron.

Silver imparts a very beautiful yellow color to glass, but it requires some caution in its mode of application. It is believed that the presence of alumina is necessary to the production of color, since a fine yellow cannot be produced unless alumina be present. A mixture of powdered clay and chloride of silver is prepared, and spread upon the surface of the glass; the glass is then reheated, and the silver penetrates to a certain depth into the glass before the latter softens. The coating is then scraped off, and the fine yellow color appears. If the silver yellow glass is held over the flame of burning wood, a peculiar opalescence is produced upon the surface, probably by the oxidation of the silver.

Uranium produces the beautiful canary yellow which is found in many articles of an ornamental kind. This glass possesses the very peculiar property of giving a green color when it is looked at, although perfectly and purely yellow when looked through. This has been attributed to the presence of iron in the commercial oxide of uranium employed; but the purer the uranium is, the more beautifully will this phenomenon be brought out. It depends upon a very remarkable physical peculiarity belonging to uranium and some other bodies.

Red. A common brownish red color is produced in glass by oxide of iron, added as ochre, or in the state of pure peroxide. Muller found ancient red glass to contain silicic acid, alkalies, lime, magnesia, alumina, protoxide of iron, and suboxide of copper.

Copper is more generally employed in coloring glass red. The use of this metal for this purpose dates from very high antiquity, and all through the middle ages it was employed to produce the reds which we see in the fine old windows left by our ancestors for our admiration. The ancient _choronzon_ was a copper red glass. Suboxide of copper is used, either in the state of commercial copper scale, or it is prepared by heating copper turnings to redness. If, during the fusion of the glass in the pot, the suboxide unites with an additional quantity of oxygen, green and not red is the result. This is avoided by combining some reducing agent with the melted substance. Glass thus colored does not exhibit its red color on heating the crucible; it is nearly colorless, or with a tinge of green even when cold; but if it is then heated a second time it assumes the red color. II. Rose supposes that a colorless neutral or acid silicate of the suboxide of copper is formed at a high temperature, and that the subsequent softening of the glass at a lower temperature causes the decomposition of this compound and a separation of a portion of the suboxide. We believe that no such chemical change takes place, and that the alteration is due, not to a change in the molecular arrangement of the particles, but to the fusion of a portion of the suboxide in the glass; or, perhaps, to an alteration in the chemical character of the particles. The suboxide of copper possesses an intense coloring power—so great, indeed, that glass colored with even a very small quantity is al-
most impermeable to light; hence it is usual merely to flash colorless glass with this colored glass, that is, to spread a very thin film of it over the colorless surface. A process for coloring glass red after its manufacture with sulphide of copper has been introduced by Bedford.

Gold can, according to circumstances, be made to impart a ruby, Carmine, or pink tint to glass. The purple of Cassius was employed, but Dr. Fuss first showed that a mere solution of gold without the presence of tin, as in the salt named, is capable of producing rose and Carmine colored glass.

Similar changes to those already described with copper occur with the salts of gold. Perhaps the glass is colorless in the pot, and it then remains colorless when cold; but when reheated, the glass quickly assumes a light red color, which rapidly spreads from the heated point over the whole glass, and increases in intensity until it becomes nearly a black red. This colored glass can again be rendered colorless by fusion and slow cooling; its color is again produced by a repetition of the heating process. If, however, it is suddenly cooled it cannot again be made to resume its ruby color. This is also an example confirmatory in the highest degree of the view that no chemical change takes place, but that all the phenomena are due to alterations in molecular structure. The practice of flashing colorless glass with the ruby glass from gold is commonly adopted. The beautiful examples of Bohemian glass manufacture, in which we have a mixture of rich ruby and the purest crystal, are produced in this way: a globe of hot colorless glass is taken from the pot, and a cake of ruby glass, prepared with a composition called schneebase, is warmed and brought into contact with the melted globe; this ruby glass rapidly diffuses itself over the surface, and the required article is blown or moulded with a coating of glass, colored ruby by gold, of any required thickness.

Schneebase is prepared with 500 parts of silica, 800 of minium, 100 of nitre, and the same quantity of potash. A very small portion of a solution of gold in aqua regia is intimately mixed with 500 parts of schmelze, 43 parts of prismatic borax, 3 or 4 of oxide of tin, and a similar quantity of oxide of antimony. This mixture is heated for twelve hours in an open crucible placed in a flat furnace, and then cooled slowly in an annealing-oven. A Bohemian ruby, especially so called, is prepared by melting together fulminating gold rubbed in with oil of turpentine, quartz powdered, and tretted minium, sulphide of antimony, peroxide of manganese, and potash. Böhme has given an analysis of a Venetian ruby glass, in which 0.5 of a grain of gold is combined with about 150 of the ordinary ingredients of glass, with some tin and iron.

Manganese is sometimes employed to give a fine amethystine color to glass; care is, however, required to prevent the reduction of the peroxide of manganese in the process.

Green. Green colors may be obtained by a variety of metallic oxides. Protioxide of iron imparts a dull green; an emerald green color is given by oxide of copper. Either copper scales or verdigris dried and powdered are employed, the color being much finer with a lead glass than with one containing no lead. Translucent or dull glass is converted into a deep blue or turquoise color by oxide of copper, and not into a green. An emerald green is also produced by the oxide of chromium. Two kinds of Bohemian green glass, known respectively as the ancient and modern green glasses, are prepared from mixtures of the oxides of nickel and of uranium.

Blue. The only fine blue is produced by cobalt. See Azure and Cobalt, vol. i.

Brown. Peroxide of manganese with zaffre yields a fine garnet-like brown.

Pink or Flesh Color. Oxide of iron and alumina, obtained by heating a mixture of alum and green vitrified.

Orange. Peroxide of iron with chloride of silver.

Jasper. A Bohemian glass, generally black, but of fine lustre, prepared by adding forge scales, charcoal, and bone ashes to the ordinary materials for glass.

GLUCINUM. The metal of Glucina has been obtained by M. H. Debray (Ann. Chym. et Phys. xlii. 5) by the following process: Into a wide glass tube are introduced two vessels, one containing chloride of glucinum, and the other sodium, deprived of the greatest part of the adhering naphtha by compression between two sheets of blotting paper. The glass tube is placed in a combustion furnace. It is then traversed by a current of hydrogen, passing from the chloride of glucinum to the sodium. The sodium is not placed in the tube until all the air has been expelled by the hydrogen. The tube is then heated just where the sodium is placed, which by this means is deprived of the last particles of naphtha, and fuses. The chloride of glucinum is then heated. The vapor of chloride, driven forward by the hydrogen, arrives over the fused sodium. It then swells up, and the heat generated by chemical action is sufficient to raise the contents of the vessel to redness, which often breaks the vessel if made of porcelain. The operation is ended when the chloride of glucinum sublimes beyond the sodium vessel. When the tube is cool the vessel is withdrawn, and in the place of the sodium a large quantity of a blackish substance is found, composed of common salt and the metal glucinum in brilliant spangles, and sometimes even
in globules. This mass is quickly detached and fused in a small crucible, with the addition of some dried common salt, which acts as a flux, and facilitates the union of the globules of metal.

It is a white metal, whose density is 2.1. It may be forged and rolled into sheets like gold. Its melting point is inferior to that of silver. It may be melted in the outer blow-pipe flame, without exhibiting the phenomenon of ignition presented by zinc and iron under the same circumstances. It cannot be set on fire in an atmosphere of pure oxygen, but in both cases is covered with a film of oxide, which seems to protect it from further action. It is not acted on by sulphur, but readily combines with chlorine and iodine by the aid of heat.

Silicium unites readily with it, forming a hard, brittle substance, capable of taking a high polish. This substance is always formed when silicium is prepared in porcelain vessels, the silica being reduced by this metal. After several fusions in such vessels, silicium may contain as much as 20 per cent. of silicium. Glucinum does not decompose water at the temperature of ebullition, nor even at a white heat.

Sulphuric and hydrochloric acids dissolve it easily, either concentrated or diluted, with the evolution of hydrogen.

Nitric acid, even when concentrated, has, at ordinary temperatures, no action upon it, and decomposes it but slowly when boiling.

Glucinum, though not acted on by ammonia, dissolves readily in caustic potash.

The metal which Wöhler obtained, by igniting chloride of glucinum with potassium in a platinum crucible, differs considerably from that just described, the metal thus obtained being a gray powder, very refractory in the furnace, but combines with oxygen, chlorine, and sulphur much more energetically than the metal described by Debray. The differences arise probably partly from the different state of aggregation, and partly from the contamination of Wöhler's metal with platinum and potassium.

Berzelius effected the solution of the beryl by fusing the finely-powdered beryl with three times its weight of carbonate of potash in a platinum crucible, and then treating the fused mass with hydrochloric acid; but the swelling up of the mixture of carbonate of potash and beryl at the moment of fusion, prevents the quantities being made at a time. To obviate this, Debray uses lime. The following is the process given by him:

The pulverized emerald is mixed with half its weight of quicklime in powder; the mixture is then fused in an earthen crucible placed in a wind-furnace; the temperature at which the fusion takes place is much lower than that required for the assay of iron. The glass thus obtained is powdered and moistened with water acidulated with nitric acid, so as to obtain a thin paste, to which is added an concentrated nitric acid, taking care to stir the mass, which is converted, in the cold, but better by heat, into a homogeneous jelly; this is evaporated to drive off the excess of acid, then heated so as to decompose the nitrates of alumina, glucina, and iron. It is advisable to raise the temperature at the end of the operation so as to decompose a small portion of the nitrate of lime. The result of this calcination is composed of insoluble silica, alumina, glucina, and sesquioxide of iron, insoluble in water, finally, nitrate of lime, and a little free lime. It is boiled with water containing some chloride of ammonium.

The nitrate of lime is rapidly removed by the water, and the lime decomposing the chloride of ammonium is also at length dissolved, with liberation of ammonia. This disengagement of ammonia ceases as soon as all the lime is dissolved, and as it is the surest guarantee of the non-solution of the alumina and glucina, the calcination of the nitrates should be repeated, unless ammonia is liberated under the circumstances just mentioned. The residue of silica, alumina, glucina, and iron is well washed until all the lime is removed, which is known by oxalate of ammonia causing no cloudiness in the washings.

The separation of the silica and the earths is easily effected, mere boiling with nitric acid dissolving the alumina, glucina, and iron, and leaving the silica undissolved. The solution of the nitrates of alumina, glucina, and iron is then poured into a solution of carbonate of ammonia, to which a little ammonia has been added. The precipitation of the earths takes place without liberation of carbonic acid, and the glucina at length redissolves in the carbonate of ammonia. The solution of the glucina may be considered complete after seven or eight days' digestion. As the carbonate of ammonia may dissolve a little iron, it is better to add to the solution a few drops of sulphide of ammonium, which precipitates it completely. The solution is then filtered and boiled to drive off the carbonate of ammonia, when the glucina is precipitated in the state of carbonate.

The carbonate of glucina is a dense white powder, easily washed; it is collected on a filter and dried.

From the carbonate any of the other compounds of glucina may be easily prepared; simple calcination converts it into glucina. A process for the separation of alumina and glucina has been proposed by M. Berthier; it consists in suspending the well-washed earths in water, and passing a current of sulphurous acid through them. Their solution is complete. The liquid is then boiled to expel the excess of sulphurous acid, when a dense sub-
sulphite of alumina is precipitated, leaving the glueina in solution. Debray found that sometimes in this process the glueina was entirely precipitated with the alumina.

Chloride of glueina is prepared by the same process as the chloride of aluminium, merely substituting glueina for alumina, and at first sight very much resembles it; it is, however, much more volatile than chloride of aluminium, being about as volatile as chloride of zinc. It differs also from chloride of aluminium inasmuch as it is not capable of forming definite compounds with some protochlorides; chloride of aluminium uniting with certain protochlorides forming a series of compounds, fusible at a low temperature, volatile at a red heat without decomposition; and the composition of which is represented by the formula \( \text{AlCl}_3 \cdot \text{MC1} \). The crystals of chloride of aluminium may be called chlorinated spindles, and are easily obtained, it being only necessary, in order to form the sodium compound of the group, to mix the chloride of aluminium with half its weight of common salt, and distil, one distillation producing it pure, the formula of it being \( \text{AlCl}_3 \cdot \text{NaCl} \). Chloride of glueina is very soluble in water; it may, however, be obtained in crystals, by allowing its solution to evaporate over sulphuric acid under a bell jar. The presence of a little free hydrochloric acid favors the crystallization. Thus obtained, this salt is a hydrate, and according to Awdlejew its formula is \( \text{GlCl}_4 \cdot 4\text{HO} \). The hydrated chloride of glueina is decomposed by heat into hydrochloric acid and glueina.

Iodide of glueina.—This compound presents all the characters of the chloride, only being a little less volatile. The affinity of iodine for glueina is not very strong, oxygen decomposing the iodide at the heat of a spirit lamp, liberating iodine and forming glueina. Glueina is also capable of combining with fluorine, the double fluoride of glueina and potassium being formed by pouring a solution of fluoride of potassium into a salt of glueina. It is but little soluble in the cold, and is deposited in the form of brilliant scales.

Sulphate of glueina.—This salt is white, has an acid and slightly sweet taste. It is unalterable in the air at ordinary temperatures, but effloresces in dry and warm air. By heat it first fuses, in its water of crystallization, then at a red heat is decomposed into sulphurous acid, oxygen, and glueina.

Water at 67.2° F. (14° C.) dissolves about its own weight of this salt; its solubility is increased by heat, and boiling water dissolves an indefinite quantity. The presence of free sulphuric acid or alcohol lessens its solubility.

It loses a portion of its acid in many cases with facility; for instance we obtain an uncrystallizable tribasic sulphate of glueina, by dissolving carbonate of glueina in a concentrated solution of the sulphate; carbonate of glueina is added until carbonic acid ceases to be liberated at each addition; the liquid, filtered and evaporated, gives a gummy residue. The very dilute solution of this salt lets fall some glueina, and is changed into a bisulphate, also uncrystallizable.

Sulphate of glueina dissolves zinc with disengagement of hydrogen, forming a bisulphate of glueina and sulphate of zinc. Sulphate of alumina, under the same circumstances, dissolves zinc with liberation of hydrogen, and forms a sulphate of zinc and an insoluble sulphate of alumina. Taking advantage of this difference, Debray proposed a method (\textit{Lun. Chym. et Phys. xlix. 26}) for the separation of glueina and glueina, but
GLYCERINE.

which does not answer for analytical purposes, as chemically pure zinc is only acted on with great difficulty by these sulphates. Sulphate of glucaea is formed by dissolving the carbonate in dilute sulphuric acid, the evaporated liquid depositing it on cooling. It is essential to keep the liquid distinctly acid; it assists the crystallization, and besides, if we were to dissolve the carbonate in it until the liberation of carbamic acid ceased, we should obtain a basic uncrystallizable salt. According to Awdejew the formula of this salt is

\[ \text{GI}_3\text{O}_2\text{S} + 4\text{H}_2\text{O} \]

Double sulphate of glucaea and potash.—This salt was discovered by Awdejew; he obtained it while endeavoring to produce the double sulphate of glucaea and potash corresponding to common alum, (which, had he succeeded, would have been one of the best proofs of the analogy existing between alumina and glucaea.)

It is obtained in crystalline crusts, by evaporating a solution containing 15 parts of sulphate of glucaea to 14 parts of sulphate of potash. The concentration is stopped as soon as the liquid becomes turbid; at the end of a few hours this salt is deposited, which is purified by recrystallization. It is precipitated as a crystalline powder by the addition of sulphuric acid to the concentrated solution. It is but little soluble in the cold, much more so, though slowly, in hot water. By the action of heat it first fuses in its water of crystallization, then is decomposed entirely into glucaea and sulphate of potash, if the heat is strong and long enough applied. Its composition is represented by the formula

\[ \text{GI}_3\text{O}_2\text{S} + \text{K}_2\text{O},\text{SO}_3 + 2\text{H}_2\text{O} \]

Carbonate of glucaea.—Glucaea is soluble in carbonate of ammonia. When the solution is boiled, carbonate of ammonia is driven off, and a precipitate of carbonate of glucaea is formed, the composition of which seems to be

\[ 3\text{GI}_3\text{O},\text{CO}_3 + 5\text{H}_2\text{O} \]

but if we arrest the boiling as soon as the solution becomes turbid, we obtain a solution of a double carbonate of glucaea and ammonia, from which, by the addition of alcohol, this salt is deposited in clear crystals. Double carbonate of glucaea and ammonia is white, very soluble in cold water, but is easily decomposed by hot water, liberating carbonate of ammonia and depositing carbonate of glucaea. It is much less soluble in dilute alcohol, and nearly insoluble in absolute alcohol. It is easily decomposed by heat, leaving as a residue pure glucaea.

It is also decomposed by exposure to the air after some time. According to Debay the formula of this salt is

\[ 4\text{GI}_3\text{O},\text{CO}_3\text{H}_2\text{O} + 3(\text{NH}_3\text{O},\text{CO}_3) \]

There also exists a double carbonate of potash and glucaea corresponding to this salt, and is prepared by the same process, merely substituting carbonate of potash for carbonate of ammonia; the carbonate of potash, however, takes longer to dissolve the glucaea than carbonate of ammonia.

Oxalic acid dissolves glucaea, but does not yield any crystallizable compounds, except in combination with other oxalates, as the oxalate of potash or ammonia. These double salts crystallize well and have the following simple composition:

\[ \text{GI}_3\text{O},\text{CO}_3 + \text{K}_2,\text{CO}_3 \]

\[ \text{GI}_3\text{O},\text{CO}_3 + \text{NH}_3\text{O},\text{CO}_3 \]

These salts are obtained by dissolving carbonate of glucaea in binoxalate of ammonia or potash in the cold, until carbamic acid ceases to be given off. They decompose by the application of heat. The composition of glucaea is still undecided; Berzelius regarding it as a sesquioxide, and Awdejew and others as a protoxide. The latter view gives greater simplicity in the formula of its compounds, but glucaea has no decided analogy to the ordinary class of protoxides, lime and magnesia, &c.—H. K. B.

GLYCERINE. Glycerine is one of the products of the saponification of fats or oils. It is produced in large quantities in the soap manufactories in a very impure state, being contaminated with saline and empyreumatic matters, and having a very strong disagreeable odor. In order to obtain glycerine from this source, the residuary liquors are evaporated and treated with alcohol, which dissolves out the glycerine. The alcohol having been separated by evaporation, the glycerine is diluted with water, and boiled with animal charcoal. This process must be repeated several times, or until the result is sufficiently free from smell. It is, however, difficult to obtain pure glycerine from this source, on account of the nature and condition of the ingredients usually employed in making soap, which is almost impossible to deprive of rancid odor.

The compounds of glycerine with the fatty acids constitute the various kinds of fats and oils, but the base does not appear to have the same composition in all. A certain quantity of water appears to separate, and the equivalent of glycerine to be in some fats but half what it is in others. Thus the glycerine of the palm oil has the formula $\text{CH}_3\text{O}$, and the glycerine of myristine, or nutmeg butter, $\text{C}_9\text{H}_18\text{O}$, of which bodies the common glycerine should be the hydrate.
Glycerine is now obtained in great quantities from palm oil, in the process of purification for candles. It is employed with much advantage to preserve soft-bodied animals. It is manufactured into soap, is administered internally, and is supposed to possess highly nutritive properties. It has been employed in cases of deafness, and in diseases of the throat. By some it is used to preserve collision plates in a state of sensitiveness for many days.

Gneiss may be called stratified, or, by those who object to that term, foliated granite, being formed of the same materials as granite, namely, felspar, quartz, and mica.—Lyell.

Gneiss might, indeed, in its purest and most typical form, be termed schistose granite, consisting, like granite, of felspar, quartz, and mica; but having those minerals arranged in layers or plates, rather than in a confused aggregation of crystals.—Jukes.

In whatever state of aggregation the particles of gneiss may have been originally deposited, we know now that it is a hard, tough, crystalline rock, exhibiting curved and twisted lines of stratification, and composed in the main of quartz, felspar, mica, and hornblende. Mineralogically speaking, it differs from the granite rocks with which it is associated chiefly in this, that while the crystals of quartz, felspar, &c., are distinct and entire in granite, in gneiss they are broken, water-worn, and confusedly aggregated. Hence the general belief is, that gneiss or gneissose rocks are but the particles of granite weathered and worn, carried down by streams and rivers, and deposited in the seas of that early period.—Page.

**Gobelins Manufactory.** This establishment, which has been long celebrated for its tapestry, took its name from the brothers Gobelins. Giles Gobelins, a dyer at Paris, in the time of Francis I., had found out an improvement in the then usual scarlet dye; and as he lived in the rue du Bievre, in the suburbs of St. Maureian, he erected on it a large dye house, which, out of ridicule, was called **Folie Gobelins, (Rabelais.)** About this period a Flemish painter, whom some name Peter Kock, and others Kloek, and who had travelled a long time in the East, established, and continued to his death in 1550, a manufactory for dyeing scarlet cloth by an improved process. Through the means of Colbert, minister of Louis XIV., one of the Gobelins learned the process employed for preparing the German scarlet dye from one Gluck, whom some consider to be Gulich, (who was said to have learned to dye scarlet from one Kufflar, a dyer at Leyden,) and others as Kloek; and the Parisian scarlet dye soon rose into so great repute that the populace imagined that Gobelin had acquired the art from the devil. It is known that Louis XIV., by the advice of Colbert, purchased Gobelin's building from his successor in 1667, and transformed it into a palace, to which he gave the name of **Hotel Royal des Gobelins,** and which he assigned for the use of first-rate artists, particularly painters, weavers of tapestry, and others.—Beckmann.

The national manufactory is now alone remarkable for its production in textile manufacture of some of the finest works of art; and not only does it excel in the high character of its designs, but also in the brilliancy and permanence of its colors.

**Gold.** The mineral formations in which this metal occurs are the crystalline primitive rocks, the compact transition rocks, the trachytic and trap rocks, and alluvial grounds. Sir Roderick Murchison says, in his chapter On the Original Formation of Gold, in his "Silurian": "We may first proceed to consider the nature and limits of the rich gold-bearing rocks, and then offer proofs, that the chief auriferous wealth, as derived from them, occurs in superficial districts. Appealing to the structure of the different mountains, which at former periods have afforded, or still afford, any notable amount of gold, we find in all a general agreement. Whether referring to past history, we cast our eyes to the countries watered by the sources of the Golden Tagus, to the Phrygia and Thrace of the Greeks and Romans, to the Bohemia of the Middle Ages, to tracts in Britain which were worked in old times, and are now either abandoned, or very slightly productive, or to those chains in America or Australia which, previously unsearched, have in our times proved so rich, we invariably find the same constants in nature. In all these lands, gold has been imparted abundantly to the ancient rocks only, whose order and succession we have traced, or their associated eruptive rocks. Sometimes, however, it is also shown to be diffused through the body of such rocks, whether of igneous or of aqueous origin. The stratified rocks of the highest antiquity, such as the oldest gneiss and quartz rocks, (like those, for example, of Scandinavia and the northern Highlands of Scotland,) have very seldom borne gold; but the sedimentary accumulations which followed, or the Silurian, Devonian, and carboniferous, (particularly the first of these three,) have been the deposits which, in the tracts where they have undergone a metamorphosis or change of structure by the influence of igneous agency, or other causes, have been the chief sources whence gold has been derived."

In the counties of Renfrew, Ayrshire, and the meres of Mith, great piles of ancient drift gravel having been removed for the extraction of gold, the eroded edges of highly inclined crystalline limestones have been exposed, which from being much nearer the centre of the chain than the above, are probably of Silurian or Devonian age. It is from the adjacent eruptive
serpentinous masses and slaty rocks \( b \) that the gold shingle \( c \) (usually most auriferous near the surface of the abraded rock \( a \)) has been derived. The tops of the highly inclined beds \( a \) are in fact rounded off, and the interstices between them worn into holes and cavities, as

![Diagram](image)

if by very powerful action of water. Now here, as at Berezovsk, mammoth remains have been found. They were lodged in the lowest part of the excavation, at the spot marked \( w \), and at about fifty feet beneath the original surface of overlying coarse gravel \( e \), before it was removed by the workmen from the vacant space under the dotted line. The feeble influence of the streams \( n \) which now flow, in excavating even the loose shingle, is seen at the spot marked \( o \), the bed of the rivulet having been lowered by human labor from its natural level \( o \) to that marked \( n \) for the convenience of the diggers.—Murchison.

It was from the fillings of one of the gravelly depressions between these elevations, south of Miask, that the largest lump of solid gold was found, of which at that time (1824) there was any record. This "pepita" weighs ninety-six pounds troy, and is still exhibited in the museum of the Imperial School of Mines at St. Petersburg.

**Report of the production of Gold since its discovery in California.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Bullion</th>
<th>Coin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1848</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1849</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1850</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1851</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1852</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Bullion</th>
<th>Coin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1855</td>
<td>$54,114,995</td>
<td>-</td>
</tr>
<tr>
<td>1856</td>
<td>28,689,946, of which from San Francisco, $6,947,404</td>
<td>-</td>
</tr>
<tr>
<td>1857</td>
<td>31,300,980</td>
<td>9,922,257</td>
</tr>
</tbody>
</table>

The gold, the production of foreign countries, imported into the United States for the years ending 30th June, was as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Bullion</th>
<th>Coin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1853</td>
<td>$698,237</td>
<td>-</td>
</tr>
<tr>
<td>1853</td>
<td>465,044</td>
<td>-</td>
</tr>
<tr>
<td>1854</td>
<td>1,729,711</td>
<td>-</td>
</tr>
<tr>
<td>1855</td>
<td>404,317</td>
<td>-</td>
</tr>
<tr>
<td>1856</td>
<td>114,289</td>
<td>-</td>
</tr>
<tr>
<td>1857</td>
<td>151,585</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Bullion</th>
<th>Coin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1853</td>
<td>$47,916,447 25/100</td>
<td>$3,040,802</td>
</tr>
<tr>
<td>1853</td>
<td>46,289,049 25/100</td>
<td>1,962,312</td>
</tr>
<tr>
<td>1854</td>
<td>8,781,080 25/100</td>
<td>1,013,253</td>
</tr>
<tr>
<td>1855</td>
<td>688,585</td>
<td>-</td>
</tr>
<tr>
<td>1856</td>
<td>876,046</td>
<td>-</td>
</tr>
<tr>
<td>1857</td>
<td>6,503,051</td>
<td>-</td>
</tr>
</tbody>
</table>

Total in 1853 1854 - - \$34,906,100 44/100 51,234,508 28/100

The history of the production of gold in California and the States of the Union, is well told in the following table, showing the deposits of gold in the limits of the United States. These have been supplied for this work by the obliging kindness of Mr. Rockwell, of Washington.

<table>
<thead>
<tr>
<th>Period</th>
<th>Georgia</th>
<th>Alabama</th>
<th>Tennessee</th>
<th>North Carolina</th>
<th>South Carolina</th>
<th>Virginia</th>
<th>Other States</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1846 to 1847</td>
<td></td>
<td></td>
<td></td>
<td>55,305</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
</tr>
<tr>
<td>1847 to 1848</td>
<td>571,000</td>
<td>139,324</td>
<td>4,900</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
</tr>
<tr>
<td>1848 to 1849</td>
<td>1,003,000</td>
<td>188,304</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
</tr>
<tr>
<td>1849 to 1850</td>
<td></td>
<td>129,382</td>
<td>4,900</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
</tr>
<tr>
<td>1850 to 1851</td>
<td>53,490</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
<td></td>
</tr>
<tr>
<td>1851 to 1852</td>
<td>49,100</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
<td></td>
</tr>
<tr>
<td>1852 to 1853</td>
<td>49,100</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
<td></td>
</tr>
<tr>
<td>1853 to 1854</td>
<td>49,100</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
<td></td>
</tr>
<tr>
<td>1854 to 1855</td>
<td>49,100</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
<td></td>
</tr>
<tr>
<td>1855 to 1856</td>
<td>49,100</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
<td></td>
</tr>
<tr>
<td>1856 to 1857</td>
<td>49,100</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
<td></td>
</tr>
<tr>
<td>1857 to June 30</td>
<td>49,100</td>
<td>15,526</td>
<td>12,400</td>
<td>771,000</td>
<td>5,700</td>
<td>12,400</td>
<td>789,700</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2,582,500</td>
<td>439,000</td>
<td>136,100</td>
<td>904,000</td>
<td>1,871,000</td>
<td>110,000</td>
<td>198,400</td>
<td>4,979,700</td>
</tr>
</tbody>
</table>

Statement of Gold of Domestic Production deposited at the Mint of the United States and its Branches, to the close of the Year ending June 30, 1857.
### 2. Branch Mint, San Francisco.

<table>
<thead>
<tr>
<th>Period</th>
<th>California</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars</td>
<td>Dollars</td>
</tr>
<tr>
<td>1854</td>
<td>-</td>
<td>10,842,281-23</td>
</tr>
<tr>
<td>1855</td>
<td>-</td>
<td>20,860,427-20</td>
</tr>
<tr>
<td>1856</td>
<td>-</td>
<td>29,209,218-24</td>
</tr>
<tr>
<td>1857 to June 30</td>
<td>-</td>
<td>12,526,826-95</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>-</td>
<td>73,438,765-60</td>
</tr>
</tbody>
</table>

### 3. Branch Mint, New Orleans.

<table>
<thead>
<tr>
<th>Period</th>
<th>North Carolina</th>
<th>South Carolina</th>
<th>Georgia</th>
<th>Alabama</th>
<th>Tennessee</th>
<th>Other Sources</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
</tr>
<tr>
<td>1833-47</td>
<td>-</td>
<td>7,564</td>
<td>61,068</td>
<td>149</td>
<td>-</td>
<td>-</td>
<td>131,068</td>
</tr>
<tr>
<td>1848</td>
<td>1,453</td>
<td>2,317</td>
<td>6,117</td>
<td>1,214</td>
<td>-</td>
<td>-</td>
<td>10,893</td>
</tr>
<tr>
<td>1849</td>
<td>-</td>
<td>4,062</td>
<td>662,951</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>469,019</td>
</tr>
<tr>
<td>1850</td>
<td>-</td>
<td>-</td>
<td>1,560</td>
<td>457,056</td>
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<td>-</td>
<td>483,074</td>
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<tr>
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<td>-</td>
<td>1,049</td>
<td>5,800</td>
<td>6,592</td>
<td>-</td>
<td>-</td>
<td>13,107</td>
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<td>1852</td>
<td></td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>2,000,023</td>
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<tr>
<td>1853</td>
<td>-</td>
<td></td>
<td>943,331</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>943,331</td>
</tr>
<tr>
<td>1854</td>
<td>-</td>
<td></td>
<td>411,347</td>
<td>1,140</td>
<td>-</td>
<td>-</td>
<td>413,487</td>
</tr>
<tr>
<td>1855</td>
<td>-</td>
<td></td>
<td>283,344</td>
<td>921</td>
<td>-</td>
<td>-</td>
<td>284,265</td>
</tr>
<tr>
<td>1856</td>
<td>-</td>
<td></td>
<td>120,324</td>
<td>29</td>
<td>-</td>
<td>-</td>
<td>120,619</td>
</tr>
<tr>
<td>1857 to June 30</td>
<td>-</td>
<td></td>
<td>74</td>
<td>7290</td>
<td>-</td>
<td>-</td>
<td>7297</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>-</td>
<td>741</td>
<td>16,217</td>
<td>-</td>
<td>2,719</td>
<td>-</td>
<td>21,708</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Period</th>
<th>North Carolina</th>
<th>South Carolina</th>
<th>California</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
</tr>
<tr>
<td>1838 to 1847</td>
<td>-</td>
<td>1,529,777</td>
<td>143,941</td>
<td>-</td>
</tr>
<tr>
<td>1848</td>
<td>-</td>
<td>339,075</td>
<td>11,110</td>
<td>1,067,718</td>
</tr>
<tr>
<td>1849</td>
<td>-</td>
<td>278,223</td>
<td>12,509</td>
<td>390,732</td>
</tr>
<tr>
<td>1850</td>
<td>-</td>
<td>307,289</td>
<td>13,009</td>
<td>320,290</td>
</tr>
<tr>
<td>1851</td>
<td>-</td>
<td>275,472</td>
<td>25,478</td>
<td>316,661</td>
</tr>
<tr>
<td>1852</td>
<td>-</td>
<td>337,604</td>
<td>64,934</td>
<td>430,900</td>
</tr>
<tr>
<td>1853</td>
<td>-</td>
<td>227,847</td>
<td>61,845</td>
<td>305,656</td>
</tr>
<tr>
<td>1854</td>
<td>-</td>
<td>188,277</td>
<td>19,661</td>
<td>216,666</td>
</tr>
<tr>
<td>1855</td>
<td>-</td>
<td>196,894</td>
<td>13,277-17</td>
<td>229,171</td>
</tr>
<tr>
<td>1856</td>
<td>-</td>
<td>167,255</td>
<td>8,237-20</td>
<td>175,492</td>
</tr>
<tr>
<td>1857 to June 30</td>
<td>-</td>
<td>75,696-47</td>
<td>-</td>
<td>75,696-47</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>-</td>
<td>4,033,189-97</td>
<td>366,695-17</td>
<td>4,407,884-16</td>
</tr>
</tbody>
</table>

### 5. Branch Mint, Dahlonega, Georgia.

<table>
<thead>
<tr>
<th>Period</th>
<th>North Carolina</th>
<th>South Carolina</th>
<th>Georgia</th>
<th>Tennessee</th>
<th>Alabama</th>
<th>California</th>
<th>Other Sources</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
<td>Dollars</td>
</tr>
<tr>
<td>1838-47</td>
<td>63,031</td>
<td>15,427</td>
<td>2,978,852</td>
<td>32,125</td>
<td>47,711</td>
<td>-</td>
<td>-</td>
<td>3,319,017</td>
</tr>
<tr>
<td>1848</td>
<td>5,184</td>
<td>8,151</td>
<td>321,376</td>
<td>2,474</td>
<td>4,675</td>
<td>-</td>
<td>-</td>
<td>371,793</td>
</tr>
<tr>
<td>1849</td>
<td>4,162</td>
<td>7,229</td>
<td>225,224</td>
<td>2,441</td>
<td>3,061</td>
<td>-</td>
<td>-</td>
<td>264,141</td>
</tr>
<tr>
<td>1850</td>
<td>4,500</td>
<td>5,100</td>
<td>304,473</td>
<td>1,200</td>
<td>1,500</td>
<td>-</td>
<td>-</td>
<td>306,173</td>
</tr>
<tr>
<td>1851</td>
<td>1,071</td>
<td>3,293</td>
<td>154,723</td>
<td>2,251</td>
<td>2,109</td>
<td>-</td>
<td>-</td>
<td>189,283</td>
</tr>
<tr>
<td>1852</td>
<td>441</td>
<td>57,543</td>
<td>81,121</td>
<td>750</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>99,392</td>
</tr>
<tr>
<td>1853</td>
<td>2,615</td>
<td>30,905</td>
<td>50,994</td>
<td>149</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>86,258</td>
</tr>
<tr>
<td>1854</td>
<td>5,915</td>
<td>15,988</td>
<td>47,824</td>
<td>273</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>56,125</td>
</tr>
<tr>
<td>1855</td>
<td>3,146-92</td>
<td>2,110-27</td>
<td>126,558-96</td>
<td>106-42</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>143,146-29</td>
</tr>
<tr>
<td>1856</td>
<td>-</td>
<td>25,226-95</td>
<td>44,107-99</td>
<td>106-42</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>59,337-97</td>
</tr>
<tr>
<td>1857 to June 30</td>
<td>-</td>
<td>8,638-99</td>
<td>25,637-93</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>33,276-93</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>52,629-92</td>
<td>1,197,739-98</td>
<td>42,912-42</td>
<td>59,829-92</td>
<td>1,924,712-93</td>
<td>901</td>
<td>5,927,849-87</td>
<td></td>
</tr>
</tbody>
</table>
GOLD.


<table>
<thead>
<tr>
<th>Period</th>
<th>Virginia</th>
<th>North Carolina</th>
<th>South Carolina</th>
<th>Georgia</th>
<th>Alabama</th>
<th>Tennessee</th>
<th>California</th>
<th>Other Sources</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1854</td>
<td>167</td>
<td>8,464</td>
<td>1,243</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9,289,457</td>
<td>-</td>
<td>9,277,117</td>
</tr>
<tr>
<td>1855</td>
<td>2,370</td>
<td>5,790</td>
<td>2,202</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15,023,394</td>
<td>1,600</td>
<td>15,084,594</td>
</tr>
<tr>
<td>1856</td>
<td>1,025</td>
<td>950</td>
<td>2,200</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16,520,008</td>
<td>60</td>
<td>16,520,628</td>
</tr>
<tr>
<td>1857</td>
<td>1,031</td>
<td>1,699</td>
<td>2,638</td>
<td>10,434</td>
<td>-</td>
<td>-</td>
<td>9,540,257</td>
<td>1,600</td>
<td>9,541,856</td>
</tr>
<tr>
<td>June 26</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>10,998</td>
<td>19,109</td>
<td>14,780</td>
<td>68,528</td>
<td>2,128</td>
<td>1,045</td>
<td>96,073,219</td>
<td>1,600</td>
<td>96,173,529</td>
</tr>
</tbody>
</table>

Summary exhibit of the entire Deposits of Domestic Gold at the United States Mint and Branches from 1804 to the 30th June 1857.

MINTS.

<table>
<thead>
<tr>
<th>Mints</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philadelph.</td>
<td>-</td>
</tr>
<tr>
<td>San Francisco</td>
<td>-</td>
</tr>
<tr>
<td>New Orleans</td>
<td>-</td>
</tr>
<tr>
<td>Charlotte</td>
<td>-</td>
</tr>
<tr>
<td>Dahlonega</td>
<td>-</td>
</tr>
<tr>
<td>Assay Office</td>
<td>-</td>
</tr>
</tbody>
</table>

| Virginia | - | - | - | - | - | - | - | - | - |
| N'th Carolina | - | - | - | - | - | - | - | - | - |
| S'th Carolina | - | - | - | - | - | - | - | - | - |
| Georgia | - | - | - | - | - | - | - | - | - |
| Tennessee | - | - | - | - | - | - | - | - | - |
| Alabama | - | - | - | - | - | - | - | - | - |
| New Mexico | - | - | - | - | - | - | - | - | - |
| California | - | - | - | - | - | - | - | - | - |
| Total | - | - | - | - | - | - | - | - | - |

Australian Gold Mines.—The discovery of the great gold field in Australia to the westward of Bathurst, about 150 miles from Sydney, was officially made known in Great Britain, by a despatch from Sir C. A. Fitzroy to Earl Grey, on the 18th September, 1851, many persons with a tin dish having obtained from one to two ounces per day. On the 25th of May, he writes that lumps have been obtained varying in weight from one ounce to four pounds. On the 29th of May, he writes that gold has been found in abundance, that people of every class are proceeding to the locality, that the field is rich, and from the geological formation of the country, of immense area. By assay the gold is found to consist of 911 of that metal, and about 8.333 of silver, with a little base metal; or of 32 carats in fineness. July 17th, a mass of gold weighing 100 pounds was found imbedded in the quartz matrix, about 53 miles from Bathurst; and much more, justifying the anticipations formed of the vast richness and extent of the gold field in this colony. This magnificent treasure, the property of Dr. Kerr, surpassed the largest mass found in California, which was 23 pounds, and that in Russia, which was 70 pounds, now in the museum at St. Petersburg. One party of six persons got at the same time £400 in ten days by means of a quicksilver machine; and a party of three, who were unsuccessful for seven days, obtained in five days more than 200 ounces. A royalty of 10 per cent, was ordered to be paid on gold in matrix if found in Crown lands, and 5 per cent, if found in private property.

Numerous claims have been made by persons who have thought that they had given the first indications of gold in Australia. To Sir Roderick Murchison is, however, due the merit of pointing out that gold might probably be found in Australia, long before it was known in Europe that gold existed in that important colony. Sir Roderick Murchison thus gives us the facts: “Having in the year 1844 recently returned from the austere Urals, I had the advantage of examining the numerous specimens collected by my friend Count Szulecki along the eastern chain of Australia. Seeing the great similarity of the rocks of those two distant countries, I could have little difficulty in drawing a parallel between them; in doing which I was naturally struck by the circumstance that no gold had yet been found in the Australian range, which I termed in anticipation the ‘Cordillera,’ impressed with the conviction that gold would sooner or later be found in the great British Colony. I learnt in 1846 with satisfaction that a specimen of the ore had been discovered. I thereupon encouraged the unemployed miners of Cornwall to emigrate, and dig for gold as they dug for tin in the gravel of their own district. These notices were, as far as I know, the first printed documents relating to Australian gold.

August 23th, 1851, Lieutenant-Governor C. J. Latrobe announced to Earl Grey from Melbourne, the discovery of large deposits of gold in that district of the colony. In a second Parliamentary blue book, issued February 3, 1852, it is stated that 79,340 ounces of gold, worth £257,855 7s., had been previously forwarded to England; and that the gold
fields of the colony of Victoria rival, if they do not exceed in value, the first discovered gold fields of New South Wales; the total value being then £2,000,000; and but a little time afterwards about half a million sterling. Mr. E. Hargraves, commissioner for Crown lands, announced from Bathurst, that no part of California which he had seen has produced gold so generally and to such an extent as Summerhill Creek, the Turon River and its tributaries.

For the purpose of conveying a correct idea of the conditions under which the greatest quantity of the Australian gold occurs, three plans have been selected from different districts. The first of these (fig. 313) represents a longitudinal section along the course of the west quartz vein in the Clunes gold-mining field. We have here, as indicated by the darker portions of the wood-cut, the quartz vein shown in section, with the shafts sunk, and the levels driven upon it. The lighter portions of the figure resting on the quartzose rock is an auriferous drift; and on the left of the section the great basaltic formation is shown.

![Figure 313](image)

Fig. 314 is a section of a portion of the Ballarat gold field. It is an east and west section from the Red Streak-lead across Post-office Hill, White Flat, the township of Ballarat West, and the quartz reef west of the township; and it shows the auriferous drift, schist, quartz, and basaltic formations of the district. In those two sections, we have, therefore, all the conditions shown of the processes of mining on the quartz lodes and in the alluvial deposits.

Fig. 315 is a section from the Boroomdara and Bulleen gold mines, a few miles from the capital of Victoria. It is the east and west section of the Carlton Estate quartz reef, and is mainly given to illustrate the unskilful and dangerous condition of many of the workings undertaken by men who have no experience in subterranean operations. The shaft, if such it can be called, is about 40 feet deep; and the reef dips with the solid strata at an angle of about 60 degrees to the horizon.

The wall of the shaft at A is not supported on the footwall by props and proper timbering,
which it should be, as indicated by E E E. The windlass at c and the framework at d are both exceedingly insecure. This is the mode of proceeding in a very important working, where almost every piece of quartz broken out contains gold, and also antimony and iron. At the point r the quartz reef was exceedingly rich, and there it branches off into small strings, yielding 22 ounces of gold to the ton.

It is not necessary here to trace the progress of gold-mining in this colony. The quantity of gold discovered and exported has been enormous. Some exceedingly large "nuggets" have been found; one in Forest Creek, weighing 27 lbs. 6 oz. 15 dwt, and the Welcome Nugget, weighing 2,217 oz. 16 dwt.

The produce of the gold fields of Victoria in 1856 was as follows:

The quantities brought to Melbourne and Geelong by escort,

From Castlemain and out-stations " Sandhurst and do. " Maryborough and do. " Ballarat and do. " Beechworth and do. Dusted by private hand Brought by private hand Quantity which has evaded duty In the treasury banks at camp, &c., and in transit Total

- - - - - - 372,997 - - - - - - 599,100 - - - - - - 337,709 - - - - - - 1,009,522 - - - - - - 334,709 2,644,237 - 824,322 3,947,160 oz.

The exports of gold from Australia since 1851 have been as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1851</td>
<td>£307,118</td>
<td>1855</td>
<td>£1,513,219</td>
</tr>
<tr>
<td>1852</td>
<td>9,735,903</td>
<td>1856</td>
<td>12,740,480</td>
</tr>
<tr>
<td>1853</td>
<td>10,445,700</td>
<td>1857</td>
<td>11,784,229</td>
</tr>
<tr>
<td>1854</td>
<td>9,098,709</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The quantities of gold exported from New South Wales alone in the same periods have been:

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantities</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1851</td>
<td>ex. dwts. grs.</td>
<td>£ s. d.</td>
</tr>
<tr>
<td></td>
<td>144,120 17 16</td>
<td>465,356 0 0</td>
</tr>
<tr>
<td>1852</td>
<td>818,751 18 17</td>
<td>2,660,946 0 0</td>
</tr>
<tr>
<td>1853</td>
<td>548,052 19 21</td>
<td>1,781,172 0 0</td>
</tr>
<tr>
<td>1854</td>
<td>237,910 13 23</td>
<td>775,209 0 0</td>
</tr>
<tr>
<td>1855</td>
<td>64,384 14 3</td>
<td>205,250 0 0</td>
</tr>
<tr>
<td>1856</td>
<td>42,465 17 1</td>
<td>188,006 0 0</td>
</tr>
<tr>
<td>1857 to 31st March</td>
<td>17,088 8 0</td>
<td>64,081 10 0</td>
</tr>
</tbody>
</table>

1,872,773 9 9 | 6,095,000 10 0

The remainder being the produce of the gold fields of Victoria.

Gold has been discovered in some considerable quantities in Tasmania. It has been reported as having been found, although as yet not to any great extent, in New Zealand; and it is well known that this precious metal is found in all the islands of the eastern Archipelago.

The recent discoveries of Gold in British Columbia.—The following communication from a correspondent to the Victoria Gazette, Vancouver's Island, is especially interesting. It is dated Upper Fraser River, Nov. 28, 1858.

Magnitude of the Gold Fields of British Columbia.—"That the auriferous deposits of Vol. III.—37
this region are spread over a considerable scope of country is apparent from the fact that paying diggings have already been found on the Fraser River, extending from Fort Hope almost to Fort Alexander, a continuous distance of nearly 400 miles. Among the tributaries of this stream, Thompson and Bridge Rivers are known to be surfeits—the latter sufficiently so to have already richly rewarded those who have labored upon it at high up as 50 or 40 miles from its mouth, while the former has been ascertained to have many bars that will pay in its bed. On two of its confluentes—Nicholas and Bonaparte Rivers—good diggings are reported to have been recently discovered. How many more of the numerous branches of these streams shall yet be found abounding in gold remains to be seen, little or no prospecting having thus far been done upon them. Nor is the extent of this gold field likely to be limited to these rivers and their sources. Coarse gold was found about six weeks since by some packers while exploring for a mule route around Lake Seton. It was discovered on a large creek flowing into the outlet of the lake at a point about 15 miles from the Fraser. The dust was apparently of high standard value, at two places on the Lillooet River bars having been found that will warrant working with a sluice. The first of these is on the east side of the stream, 10 miles above Fort Douglas, where a party are now washing with sluices with very satisfactory results. When I passed the spot they had been at work but two days; the first day three men took out $14 50c., the next day, $18. They showed me the gold, which was fine, like that found on the Lower Fraser. The other bar is 20 miles above Fort Douglas. It is very extensive, and promises to pay as well as the one first named, though it has not yet been worked. Bars similar to these are abundant on the Lillooet, and the fact of those having been prospected was owing to the accident of a log cabin having been built near them, and not because they seemed more likely to contain gold than the others. For 100 miles above the Pavillon, and beyond what is termed the Canoe Country, the banks of Fraser River have been proved to pay even better than below, the gold being coarser and more easily saved, as well as more plentiful. It will thus be seen that the gold fields of British Columbia, ascertained to be paying, to say nothing of rumored discoveries beyond, are tolerably extensive. They do not, it is true, rival those of California or Australia in magnitude; but that they cover a large scope of country, and will give employment to a large population, is settled beyond controversy or question.  

**Richness of the Mines.**—"To claim that the Fraser River mines are as rich, or that labor has been generally as well rewarded in them as in the mines of California at an early day, would be idle. I might say much in explanation of the numerous failures that attended the first adventurers to these mines, without making myself their apostle—how the miners came too soon and in too great numbers—how the river kept up, and of the many disadvantages under which they labored; all might be enlarged upon were it not now well known to the public. In regard to this section, however, I may say those pioneers who worked here last winter and spring uniformly made large wages; and that those who came in since have been able to remain, paying the enormous prices they have done for provisions, prove that they must have had good paying claims most of the time. The cost of living here, with other necessary expenditures, could not have been less than $4 a day to the man, yet I find all have been able to defray their current expenses, while many have accumulated large sums—sufficiently large in a majority of cases, with those who have been here any length of time, to lay in a winter's stock of provisions, even at the present high prices. That better average wages can be made here than in any part of California at present there is no doubt. This can be done even with the present want of ditches and indifferent appliances for taking out the gold. These diggings, owing to the fineness of the dust and the difficulty of saving it, require to be worked with sluices—a mode that has been introduced to but a limited extent as yet, owing to the want of lumber as well as of wheels or ditches for supplying water. When sluices shall have been generally brought into use, more than twice the amount now realized can be taken out by hand. Another cause that will tend to render these mines highly remunerative in the aggregate is, that every man will be able to secure a claim, and that but little capital will be required for starting operations; hence every one will enjoy the full fruits of his own labor, and none need remain idle. For this winter, owing to the lateness with which provisions have been got in, much will be done; no one here expects it; the utmost that will be aimed at, as a general thing, will be to make enough to pay expenses of living, to prospect a little, and be on hand at the breaking up of winter. With the coming of spring large operations will be entered into, and all here entertain the most sanguine anticipations, or rather, I should say, fullest confidence as to the result."  

**Their durability.**—"That these mines will be found not only rich and extensive, but also lasting, I am fully satisfied. Apart from their vast extent of surface, the diggings, at one time thought to be shallow, are now known to run downward in many localities to a good depth. It has lately been ascertained that not only the bars along the river, but many of the lower benches or table lands, contain sufficient gold to pay wages can be brought upon them, which in most cases can easily be done. These benches are not only numerous, but often of great extent, and would afford employment for a large number of
GRINDING AND CRUSHING MACHINERY.

men for many years to come. Little or no search has been made as yet for drift diggings or quartz, though there are abundant indications that both, of a paying character, exist. Fine ledges of quartz, in fact, present themselves almost everywhere, though no thorough examination has been made of their quality. The banks of Bridge River consist of alternate strata of slate and quartz rock, the most favorable possible geological formation for gold. I would venture, then, after having seen considerable of the mines in this quarter, to express the confident opinion that they will prove sufficiently extensive, productive, and lasting, to warrant a large immigration to this country in the ensuing season, and that British Columbia is destined to become another great gold-producing region, ranking next to California and Australia in the amount she will hereafter annually yield of this precious commodity.

Such is a general view of the gold-producing districts of the world. Much fear has been expressed lest the influx of gold should reduce the value of that metal. Since the discovery of the Californian gold field in 1848, not less than £159,897,184 sterling has been added to the wealth of Europe and America from the great gold fields of California and Australia. This question cannot be discussed in this place, but it is one of the greatest interest, demanding alike the consideration of the politician and the social philosopher.

GOLD THREAD, or spun gold, is a flattened silver-gilt wire, wrapped or laid over a thread of yellow silk, by twisting with a wheel or iron bobbins. By the aid of a mechanism like the braiding machine, a number of threads may thus be twisted at once by one master wheel. The principal nicety consists in so regulating the movements that the successive volutions of the flanged bobbin of each thread may just touch one another and form a continuous covering. The French silver for gilding is said to be alloyed with 5 or 6 pennyweights, and ours with 12 pennyweights of copper in the pound troy. The gold is applied in leaves of greater or less thickness, according to the quality of the gilt wire. The smallest proportion formerly allowed in this country by act of parliament was 100 grains of gold to one pound, or 3,700 grains of silver; but more or less may now be used. The silver rod is immersed in the gold leaf, and the compound cylinder is then drawn into round wire down to a certain size, which is afterwards flattened in a rolling-mill.

The liquor employed by goldsmiths to bring out a rich color on the surface of their trinkets, is made by dissolving 1 part of sea-salt, 1 part of alum, 2 parts of nitre, in 3 or 4 parts of water. The pickle or sauce, as it is called, takes up not only the copper alloy, but a notable quantity of gold; the total amount of which in the Austrian empire has been estimated annually at 47,000 francs. To recover this gold, the liquor is diluted with at least twice its bulk of boiling water, and a solution of very pure green sulphate of iron is poured into it. The precipitate of gold is washed upon a filter, dried, and purified by melting in a crucible along with a mixture of equal parts of nitre and borax.

GRINDING AND CRUSHING MACHINERY. Crushing Mill. This machine was introduced into the mines of Cornwall and Devon in the early part of the present century. In its simplest form it consists of two rollers mounted in a strong iron frame, and kept in contact by means of screws; motion is communicated to one of the rolls, either by a water-wheel or steam-engine, but the other is made to revolve by the friction generated between the moving roll and the stuff to be crushed. This mill is usually employed for reducing mineral substances which have already received some mechanical preparation, but machines have been contrived with a series of rolls, set below each other, into which the stuff is introduced as brought from the lode under ground. In order to effect this operation, the upper rolls are fluted, and the lower ones have various speeds and diameters, but it may be remarked that although this arrangement has been somewhat extensively employed in the north of England, yet it has found few advocates either in Wales or Cornwall.

The practice of keeping the rolls together by screws acting on the bearings is objectionable, since the entrance of a piece of steel, or other hard substance, of greater width than the fixed opening between the rolls, immediately produces a stoppage, and strains the apparatus or otherwise causes serious breakages to some of the parts. In order to obviate these evils, the rolls are usually adjusted and kept in position by weighted levers pressing on their axes.

As the machines employed in Cornwall may be considered the most effective in operation as well as complete in their construction, that type is selected for representation.

\[ n, b (\text{fig. 316}) \] are the crushing-rollers fitted in a strong frame-work of cast iron, which is stayed by a wrought-iron bar \( b \), and firmly bolted to longitudinal beams inserted in the walls of the crushing-house. The rollers revolve in bearings, which are so arranged as to slide in grooves, and therefore admit of the cylinders being brought nearer to or separated farther from each other. To keep the rollers in contact and yet allow the action to take place, a weighted lever \( \lambda \) is placed on each side, which by means of tension bars connected with one of the bearings, keeps a constant pressure upon the rollers. The ore to be crushed is lodged upon a floor \( c \), and introduced into a hopper \( \alpha \), from which it falls between the rolls; the requisite crushing pressure being attained by increasing or decreasing the weights applied to the end of the lever. The crushed ore passes from between the rollers \( n \) into the higher extremity of an inclined cylinder \( s \), made of coarse gauze, or perforated plate,
GRINDING AND CRUSHING MACHINERY.

which being set in motion by the same power as the rollers themselves, separates the pulverized material into two classes. That portion which passes through the sieve falls into a wagon placed on the floor of the house, whilst the other, which is too large to escape through the openings, is carried to the lower end of the cylinder, from whence it passes into an inverted bucket-wheel, by which it is again conveyed into the hopper to be recrushed.

The modifications to the foregoing arrangement may be thus briefly noticed:

In some machines the feed-hopper is made of sufficient capacity to hold from 20 to 25 cwt. of stuff, which is introduced by means of a tram wagon, and renders hand feeding unnecessary. The shoot conveying the crushed ore to the rotating sieve, is sometimes divided at the bottom into two parts, one to deliver rough, and the other fine stuff. In connection with each division is a cylindrical riddle revolving and separating the work according to the fineness or coarseness of the mesh employed.

A circular sieve, divided midway into two parts, each of a different mesh, is in some instances advantageously substituted for two sets of sieves; whilst, in other cases, circular sieves are omitted, the operation of sizing being performed by fixing perforated plates on the periphery of the inverted wheel.

Instead of one roll being drawn towards the other, they are more commonly kept in contact by direct pressure, which is effected as shown in figs. 317, 318. A, lever hung to the cast-iron frame B at C, and pressing upon pin at D. When it is required to change the rollers, the pressure resulting from the lever A and weighted box E, is relieved by means of the screw-tackle F.

The considerations which should be attended to in constructing a crushing-mill, are, first to make all the parts sufficiently strong to meet the varying resistances which continually occur in crushing. For this purpose, the frame-work to receive the rolls ought to be of good cast iron, the axles of the rollers of best wrought iron, and the cylinders of the hardest and most uniform metal. To design the machine so that the matter to be crushed may be readily delivered into the hopper, sized by the circular sieves for the dressing process, and such portions as are not properly crushed, returned to the rolls without the intervention of manual labor. In order to effect this, the inverted, or raff wheel D, fig. 318,
GRINDING AND CRUSHING MACHINERY.

shown in section, ought to be made of sufficient diameter to allow the stuff, on being discharged, to descend by its own gravity into the feed-hopper. 3dly. To extend from the axis of the rollers, long tumbling shafts, A A, fig. 318, and fix on their ends the driving wheels b b, allowing a little play in the plunger blocks, so that any undue opening of the rolls may not vary the pitch line of the wheels a b, to such an extent as to endanger the safety of the teeth. 4thly. To construct the roll so that it may be readily changed, yet maintained on its axis without slipping when in motion. One of the most efficient plans for this purpose, is shown in the following wood-cut, in which a is the axis or arbor, and b the roll.

It will be seen that the cylinder roll is fitted with four internal projections; these are of the same length as the portion of the groove marked b b', but no wider than the narrower part of the groove c. When the cylinder is to be fixed on the axis, the studs are introduced into the recesses c, and the cylinder advanced into its working position, when it is turned until the studs fit into that portion of the recess between b b', and which are then wedged to the roll by a close-fitting cutter.

5thly. The diameter of the rolls should be decreased, and the length increased in proportion to the fineness of the stuff to be crushed, since a fine material requires a longer line of contact, and not so large a grip as coarser substances.

In practice it has been found advantageous to make the roller placed on the driving shaft somewhat longer than that which is opposite, and to work the rolls by spur gearing rather than by friction, since the latter is proved to furnish less economical results than the former. It has also been found injudicious to harden the rolls by chilling; hence ordinary sand-cast rolls are most frequently employed.

The speed of the rolls varies from 45 to 60 feet per minute, but this necessarily differs with the character of the stuff to be crushed. Again great variation is experienced in the quantities crushed within a given period, since a small amount of moisture in vein stuff of a certain class makes it cake, and will thus considerably reduce the produce of the mill. On the other hand, if the matter operated upon be very dry, heavy, and brittle, as in the case
GRINDING AND CRUSHING MACHINERY.

of some varieties of lead ore, the produce may be much increased, since the mill can be driven at a great speed; a less bulk will have to pass for a given weight, and there will be a smaller quantity of material carried back by the mill wheel to be regrinded.

Variable speeds have sometimes been tried in order to produce friction together with pressure at the line of contact, but it has been found that any departure from a uniform speed on the two surfaces, absorbs a considerable additional amount of power, without materially augmenting the results.

Arrastre or tahona.—This machine is extensively employed in the mining districts of Mexico, for grinding silver ores previous to their amalgamation.

It consists of a strong wooden axle \( \alpha \), (fig. 320,) moving on a spindle in a beam \( \beta \) above it, and resting on an iron pivot beneath, turning in an iron bearing, which is inserted into a post of wood \( c \), which rises about a foot above the ground in the centre of the arrastre.

The shaft \( \alpha \) is crossed at right angles by two strong spars \( \beta \), which form four arms, each about 5 feet long, one excepted, which is 9 feet long, to admit of two mules being attached to it; by this arm the machine is worked. The grinding is performed by four large porphyritic or basaltic stones, two of which are shown, \( \epsilon \). These are loosely attached by thongs of leather, or small-sized rope, to the four arms, and are dragged round over the ore, which is put in with water, until it is ground to a very fine slime or mud, called the lama. One of these machines, when in good working condition, will grind from 600 to 800 pounds weight of ore in twenty-four hours. In Guanaxato, where the best and finest grinding is obtained in the arrastres, the lining or foundation and the grinding stones are, of course, grained porphyry, and form a rough surface. The cost of this apparatus in Mexico, including the paving of the bottom, and the four metapiles or stones, is on an average £7. The original weight of a metapile is about 700 pounds, its dimensions are 2 feet 8 inches long, 18 inches broad, and 18 inches deep. Notwithstanding the hardness of the stones employed, they are so worn as to become unserviceable in the course of ten or twelve weeks; the bottom, however, is only replaced once in twelve months.

This apparatus is well suited to patio amalgamation, but it affords bad results for the power expended.

Edge mill.—This machine is employed for the purpose of reducing gold and silver ores to an impalpable powder. It is also used extensively in grinding flints, stones, slags, and a variety of other products. However much the details of this apparatus may vary, its principle is the same in all cases. Two vertical runners rotate on the outer circumferences of a flat or slightly conical basin, and afford a frictional or grinding action equal to the difference of distance performed by the inner and outer edges.

The subjoined wood-cut, fig. 321, represents a mill constructed at the Mould Foundry, Flintshire. \( \alpha \), rotating pan, resting upon frictional wheels \( \delta \); \( c \), vertical shaft firmly keyed to pan \( \alpha \), to which motion is communicated by wheel gearing \( \beta \). The runners \( \epsilon \) revolve on arm \( \gamma \), and may be of east iron or of stone bound with a ring of iron. These runners have no progressive motion, but have free play to rise or fall on axis \( c \), and in the stay slots \( \sigma \).
The following dimensions and particulars are derived from one of the edge mills recently working at the Fabrica La Constante in the province of Guadalajara, Spain:

- Diameter of edge runner: 6 feet.
- Centre 20 in., edge 18 in.
- Weight of do. do.: 3 tons, 15 cwt.
- Speed of runner: 200 feet per minute.
- Diameter of interior circle of runner: 4 feet.
- Gauge of stuff previous to its being ground: 10 holes to the linear inch.
- Do. after it leaves the mill: 60.
- Quantity of stuff reduced per 10 hours: 350 lbs.
- Horse power employed: 7.

In some machines erected at the Real-del-Monte mines in Mexico the stones were 6 feet in diameter and 12 inches wide. They were fitted with a ring of wrought iron 3 inches thick. Each pair of runners revolved round a centre on its own axis, in a cast-iron basin of which the bottom was 7 inches thick. At first good results were obtained; each mill, if kept constantly at work, ground nearly ten tons per week; but as their axles, and particularly the wrought-iron rings and cast-iron bottoms, began to wear hollow, and to lose an even surface, the grinding rapidly diminished, and with one year's work they were completely worn out.

The chief advantage of this machine is its simplicity of construction and consequent small first cost; but all its parts require to be made of great strength, and therefore of proportionate weight; hence, in addition to the rapid wear to which it is liable, this apparatus becomes objectionable for countries where transit of heavy machinery is more than ordinarily difficult and expensive.

**Horizontal mill.**—For the purpose of reducing auriferous and argentiferous ores to an exceedingly fine powder, and where dry grinding is essential, no apparatus has been found more effectual than the horizontal mill. It affords the largest area of frictional surface for
GRINDING AND CRUSHING MACHINERY.

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the least wear and tear, and accomplishes equal results at a cost not exceeding one-fourth of that incident to the edge mill.

The construction of the horizontal mill will be rendered intelligible by the aid of the following illustration, fig. 322, in which one pair of stones is shown in section. A is a cir-

cular hopper, into which the stuff to be ground is introduced; B, small pipes of sheet iron, for delivering the stuff between the surfaces of the runner c and bed-stone c'; N, casing enclosing the runner into which the ground material is delivered; r, hole in centre of runner; F, driving shaft, with continuation shaft a, for giving motion to a Jacob's ladder if requisite; u u', regulating screw for elevating runner c; x, driving wheel; k, crown wheel; l, wheel giving motion to pinions m m'; and n, vertical shaft, to drive any supplementary apparatus which may be requiring such, as sizing sieve, &c. Four pairs of stones are usually driven by the wheel l. The surface of the runner is in contact with the bed-

stone, from the periphery to within one-third of its diameter. The line of the runner then feathers upwards, in order to receive the stuff freely, and to equalize the resistance through-out the area of the bed-stone.

The following particulars will convey much practical information relative to this machine:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of stones</td>
<td>4 feet 2 inches.</td>
</tr>
<tr>
<td>Thickness of bed-stone</td>
<td>12 inches.</td>
</tr>
<tr>
<td>Ditto runner</td>
<td>14 inches.</td>
</tr>
<tr>
<td>No. of revolutions of stone per minute</td>
<td>108</td>
</tr>
<tr>
<td>Gauge of stuff in stopper</td>
<td>100 holes to the square inch.</td>
</tr>
<tr>
<td>Ditto on delivery</td>
<td>3,600 ditto</td>
</tr>
<tr>
<td>Quantity of stuff ground per 10 hours</td>
<td>1 ton per pair of stones.</td>
</tr>
<tr>
<td>Power employed in horses</td>
<td>About 5 per ditto.</td>
</tr>
<tr>
<td>Revolutions of sizing sieve</td>
<td>23 per minute.</td>
</tr>
<tr>
<td>Diameter of ditto</td>
<td>30 inches.</td>
</tr>
<tr>
<td>Length of ditto</td>
<td>108</td>
</tr>
<tr>
<td>No. of holes per square inch in sizing sieve</td>
<td>3,600.</td>
</tr>
</tbody>
</table>
GRINDING AND CRUSHING MACHINERY

<table>
<thead>
<tr>
<th>Character of runner</th>
<th>Duration of runner</th>
<th>Ditto bed-stone</th>
<th>Ditto bed-stone</th>
<th>When dressed</th>
</tr>
</thead>
</table>

From a series of practical experiments made on the same stuff by these several mills, the following results have been obtained:

<table>
<thead>
<tr>
<th>No. of Holes per square inch in Sizing sieve</th>
<th>Quantity of Stuff ground in 10 hours</th>
<th>Horse Power</th>
<th>Cost per ton.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Horizontal mill 3,600</td>
<td>20 Cwts. 19</td>
<td>5 Horse Power</td>
<td>£ 2 3 19</td>
</tr>
<tr>
<td>2. Crushing mill 3,600</td>
<td>13</td>
<td>5 Horse Power</td>
<td>£ 1 7 19</td>
</tr>
<tr>
<td>3. Edge mill 3,600</td>
<td>13</td>
<td>7 Horse Power</td>
<td>£ 6 10 19</td>
</tr>
</tbody>
</table>

J. D.

Mackworth's Patent Crushing Rollers, figs. 323 and 324, for Coal and other Minerals. These rollers are made conical to equalize the wear, and as one roller travels faster than the
GUANO.

other, the fragments are partially turned over, so as to present their weakest line of fracture to the direction of the crushing force. Less power is required to work these rollers. In lieu of the counterbalance weight usually employed to allow the rollers to separate and pass excessively hard fragments, and to bring the rollers together again, the machine is made more compact, and simplified by connecting 3 brass collars, in which the rollers work by a number of bands or cords of vulcanized india-rubber strongly stretched. A compound cord of india-rubber, 3 inches in diameter, composed of 144 small and separate cords, when stretched to double its natural length, gives a strain of 3 tons. The brass collars do not revolve.

GUANO. This extraordinary excremenitious deposit of certain sea-fowls, which occurs in immense quantities upon some parts of the coasts of Peru, Bolivia, and Africa, has lately become an object of great commercial enterprise, and of intense interest to our agricultural world. More than twenty years ago it was exhibited and talked of merely as a natural curiosity, but since that time the quantity imported into England alone has risen from 30,000 to 300,000 tons, (in 1855,) the value of which was estimated at no less than £3,000,000.

Natural History and Geography.—Huano, in the language of Peru, signifies dung; a word spelt by the Spaniards, guano.

The conditions essential for the preservation of these excrements appear to be the existence of a soil consisting of a mixture of sand and clay, in a country where the birds are allowed to live for ages undisturbed by man or man’s works, and where, moreover, the climate is very dry, free not only from rain, but also from heavy dews.

These conditions appear to have been combined to a remarkable extent on the coasts of Peru and Bolivia, between latitudes 15° north, and 21° south of the equator, for although beyond this region the flocks of cormorants, flamingoes, cranes, and other sea-fowl, appear to be equally numerous, yet the excrement is rapidly carried away by the rain or dew.

It is, then, the dryness of the climate chiefly which has permitted the guano to accumulate on these coasts; for, says Mr. Darwin: * "In Peru, real deserts occur over wide tracts of country. It has become a proverb that rain never falls in the lower part of Peru." And again: "The town of Iquique contains about 1,000 inhabitants, and stands on a little

plain of sand at the foot of a great wall of rock, 2,000 feet in height, the whole utterly desert. A slight shower of rain falls only once in very many years." Indeed since three-fifths of the constituent parts of guano are soluble in cold water Prof. Johnstone very justly

* Researches in Geology and Natural History, p. 425.
observes that," "A single day of English rain would dissolve out and carry into the sea a considerable portion of one of the largest accumulations; a single year of English weather would cause many of them entirely to disappear."

Such being the case, we might expect to find similar accumulations in other hot and dry climates, as in Egypt, and in Africa, e. g., in the neighborhood of the great desert; and only a few years since a considerable deposit of guano was found in the Koorin Mooria Islands.

The export of guano from the Chinchas Islands has increased considerably during the last few years; between 200,000 and 400,000 tons are the annual amount at present, which is effected by the aid of 900 working hands, 320 of them being Chinese, who enter into contracts to serve their employer (the Government contractor) Don Domingo Elias, for 4 dollars a month, renewing it, if they choose, with the increase of 4 dollars monthly, and a bonus of 120. Those who work on their own account are paid 8 and 10 rials, 4 and 5 shillings, for each cart that they load. They live in a collection of dirty huts made of bamboo and mud; they, nevertheless, appear to be happy and contented, and in general are well conducted. The men with picayens work their way into the guano, leaving a sort of wall on either side, (fig. 325;) here it is so hard that it requires a heavy blow to remove it. It is then conveyed in wheelbarrows either direct to the mouths of the shots or on the edge of the cliffs, or to the huge carts running on tramways for the same purpose. The color varies very much—in some parts being as dark as warm sepia, and in others as light as that of a Bath brick.

The smell of ammonia is said to be very powerful, so much so, in fact, as to affect the eyes of the workmen; crystalline deposits of various ammonical salts are also found amongst the guano. The guano heaps are surrounded by a high fence to prevent its being blown away by the wind, near the mouths of the canvas tubes or shoots, which are sometimes 70 feet long, through which it is conducted to the boats. See fig. 326.

As in Peru, the surface of the guano is covered with skeletons of birds, and bones of seals. It is also perforated by numberless holes, running in every direction, like a rabbit warren. These are made by a bird about the size of a pigeon, which remains hidden during the day, sallying forth at dark to fish. Gold and silver ornaments are also discovered occasionally, having been buried by the ancient inhabitants more than three centuries ago.

It is quite unnecessary here to insist on the value of guano as a manure. This is a point established beyond all question by nearly every agriculturist in the kingdom; and recorded by all classes of writers on agricultural subjects; it has been the means, moreover, of converting the sandy desert around Lima into a soil capable of raising abundant crops of maize; hence the Peruvian proverb, "Huano, though no saint, works many miracles."*

GUANO.

Commercial varieties.—The following appear to be the chief:

1. Peruvian.
2. Angamos.
3. Ichaboe.
4. Patagonian.
5. Saldanha Bay.
8. Indian.

Chemistry.—Guano being an article of so great value to the agriculturist as a manure, and being liable not only to adulteration to a very great extent, but also varying when genuine considerably in quality, it is highly important to have some means of ascertaining its value. This cannot be done satisfactorily by ever so experienced a dealer by mere inspection, and, therefore, both for the buyer and the seller, resort is necessary, for a knowledge of its compound parts, to the analysis of the chemist.* Such being the case, we must first ascertain the composition of genuine guano, and then inquire upon which of its several constituents its value as a manure depends.

The constitution of guano is exhibited by the following analysis of three sorts by Denham Smith.

American Guano.—Analysis of three sorts by Denham Smith.

1. Constituents soluble in hot water, (in 100 parts of guano.)

<table>
<thead>
<tr>
<th></th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphate of lime</td>
<td>0.186</td>
<td></td>
<td>0.110</td>
</tr>
<tr>
<td>Phosphate of soda</td>
<td>0.120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphate of ammonia and magnesia</td>
<td>0.584</td>
<td>0.784</td>
<td>0.133</td>
</tr>
<tr>
<td>Uric acid</td>
<td></td>
<td>2.516</td>
<td></td>
</tr>
<tr>
<td>Urate of ammonia</td>
<td>15.417</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic matter</td>
<td>1.180</td>
<td>0.860</td>
<td>0.756</td>
</tr>
</tbody>
</table>

2. Constituents soluble in cold water, (in 100 parts.)

<table>
<thead>
<tr>
<th></th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>22.200</td>
<td>20.420</td>
<td>7.700</td>
</tr>
<tr>
<td>Sulphate of potash</td>
<td>8.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphate of soda</td>
<td></td>
<td>2.944</td>
<td>19.177</td>
</tr>
<tr>
<td>Phosphate of potash</td>
<td></td>
<td>7.332</td>
<td>4.947</td>
</tr>
<tr>
<td>Phosphate of soda</td>
<td></td>
<td></td>
<td>3.60</td>
</tr>
<tr>
<td>Phosphate of ammonia</td>
<td>6.23</td>
<td>6.124</td>
<td></td>
</tr>
<tr>
<td>Phosphate of lime</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxalate of ammonia</td>
<td>7.40</td>
<td>9.39</td>
<td>10.563</td>
</tr>
<tr>
<td>Oxalate of soda</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride of potassium</td>
<td></td>
<td></td>
<td>4.163</td>
</tr>
<tr>
<td>Chloride of sodium</td>
<td></td>
<td></td>
<td>28.651</td>
</tr>
<tr>
<td>Chloride of ammonium</td>
<td>2.53</td>
<td>3.030</td>
<td></td>
</tr>
<tr>
<td>Organic matter</td>
<td>1.560</td>
<td>0.688</td>
<td>2.553</td>
</tr>
</tbody>
</table>

3. Constituents insoluble in water, (in 100 parts.)

<table>
<thead>
<tr>
<th></th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphate of lime</td>
<td>19.750</td>
<td>6.270</td>
<td>13.113</td>
</tr>
<tr>
<td>Phosphate of magnesia</td>
<td>2.030</td>
<td>0.874</td>
<td>2.580</td>
</tr>
<tr>
<td>Oxalate of lime</td>
<td>2.560</td>
<td>10.958</td>
<td></td>
</tr>
<tr>
<td>Sand, &amp;c.</td>
<td>15.60</td>
<td>0.720</td>
<td>0.120</td>
</tr>
<tr>
<td>Peroxide of iron and alumina</td>
<td>2.836</td>
<td>0.862</td>
<td>0.996</td>
</tr>
<tr>
<td>Humus</td>
<td>3.456</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic matter</td>
<td></td>
<td>4.974</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>0.041</td>
<td></td>
<td>0.403</td>
</tr>
<tr>
<td>Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Valuable as these elaborate analyses are in a scientific point of view, they are quite unnecessary for practical purposes in ascertaining the value of any given sample, for on which of these various constituents does the chief efficacy of guano depend?

* Liebig’s “Chemistry in its applications to Agriculture and Physiology,” p. 272.
Ammonia.—Undoubtedly one of the most, if not the most, important constituents of guano is the ammonia. Authors differ as to the precise manner in which ammonia and its salts act in promoting the growth, and especially in the development of the nitrogenized compounds of plants; but the fact is placed beyond dispute, whether it be that the ammonia contained in the air is decomposed by the leaves, or that the salts of ammonia are absorbed by the sponge roots of the roots in solution in water. Now, it is quite possible that, in the mysterious economy of the life of the plant, the ammonia may perform a slightly different function when in different states of combination, either with hydrochloric, sulphuric, nitric, phosphoric, carbonic, uric, humic, or oxalic acids; and although, as a general rule, we should be inclined to yield the palm in point of utility to the mere soluble combinations, yet all experience goes to show that the value of an ammoniacal manure may be measured chiefly, if not entirely, by the quantity of that compound present, and is in a great measure independent of its state of combination.

Dr. Ure drew a distinction between what he called the actual and potential ammonia, i.e., between ammonia and ammoniacal salts ready formed, and compounds, such as uric acid, which during their decay are gradually converted into ammonia. It appears that recent guano contains from 3 to 5 per cent. of uric acid, whilst the older deposits contain generally less than 1 per cent. No doubt the guano at the time of its deposition consisted chiefly of uric acid; and it is this uric acid which has become converted into salts of ammonia; for the excrements of birds which live chiefly on fish are found to contain from 50 to 80 per cent. of uric acid. It is also an established truth in agricultural chemistry that a manure which contains bodies capable of gradually yielding up any valuable compound, such as ammonia, are more useful than those which contain that compound ready formed, and in the state of soluble combinations, which the first storm of rain may wash away from the roots of the plants, where they are required. Nevertheless, admitting the truth of all this, the writer is of opinion (and he believes this is the general experience of agriculturists) that the importance of this distinction between actual and potential ammonia has been rather exaggerated; and that generally it is enough for all practical purposes, in estimating the value of a guano, to determine the total quantity of nitrogen present in every form, and to consider it as representing an equivalent quantity of ammonia "in case" or "in posse."

Potash.—Of the two alkalies, potash and soda, the soil usually contains more than sufficient soda for the supply of vegetation; it is therefore chiefly potash which it is necessary to add in the form of manure.

Besides, even the best guano always contains a considerable quantity of common salt, viz., from 1·5 to 2·5 and even 5 per cent.

Mr. Way, in his valuable paper, "On the Composition and Value of Guano," only gives the quantity of alkaline salts, not having determined the potash; but the average quantity of potash in genuine guano may be seen by referring to the analyses before given in detail, and will be found to vary from 3·5 to 4·5 per cent.

However, in estimating the value of guano the knowledge of the quantity of potash is by no means of the same importance as of the ammonia, or the phosphoric acid.

Phosphoric Acid.—The phosphoric acid is second in importance to no other constituent than the ammonia; being essential for the development of the seeds and all those parts of the vegetable organism, which serve as foods in the production and restoration of the flesh and bones of animals. It exists in the guano (as is shown by the preceding detailed analyses) in combination with ammonia, potash, soda, and lime.

In most analyses the quantity of phosphate of lime, $3\text{CaO} \cdot \text{P}_2\text{O}_5$, is given instead of phos phoric acid, $\text{P}_2\text{O}_5$ or $3\text{HO} \cdot \text{PO}_4$; but 156 parts of phosphate of lime ($3\text{CaO} \cdot \text{P}_2\text{O}_5$) correspond to 72 of phosphoric acid ($\text{P}_2\text{O}_5$), or as 18 to 6.

The amount of phosphate of lime in the several varieties of guano is as follows:—

<table>
<thead>
<tr>
<th>Guano</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From analyses of 9 samples by Way, imported in 1847-8</td>
<td>35-45</td>
<td>19-25</td>
<td>26-35</td>
</tr>
<tr>
<td>From Mr. Way's analyses of 10 samples, imported in 1848-9</td>
<td>25-50</td>
<td>21-51</td>
<td>23-49</td>
</tr>
<tr>
<td>From Mr. Way's analyses of 14 samples, imported in 1849</td>
<td>22-93</td>
<td>21-26</td>
<td>25-18</td>
</tr>
<tr>
<td>Angamos</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From 2 analyses by Dr. Ure</td>
<td>22-68</td>
<td>19-20</td>
<td>20-25</td>
</tr>
<tr>
<td>Iloboce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From 11 analyses by Dr. Ure and Mr. Teshemacher</td>
<td>37-00</td>
<td>26-90</td>
<td>31-50</td>
</tr>
<tr>
<td>Patagonian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From analyses of 14 samples by Dr. Ure and Mr. Teshemacher</td>
<td>65-5</td>
<td>29-3</td>
<td>47-4</td>
</tr>
<tr>
<td>Sal direction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From analyses of 9 samples by Mr. Way</td>
<td>60-95</td>
<td>48-91</td>
<td>54-98</td>
</tr>
<tr>
<td>From analyses of 9 samples by Dr. Ure and Mr. Teshemacher</td>
<td>62-5</td>
<td>51-9</td>
<td>56-7</td>
</tr>
<tr>
<td>Bocas de Espana</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From analyses of 3 samples by Mr. Nebit</td>
<td>25-26</td>
<td>2-99</td>
<td>14-15</td>
</tr>
<tr>
<td>From analyses of 3 samples by Mr. Apjohn</td>
<td>25-26</td>
<td>5-84</td>
<td>17-17</td>
</tr>
</tbody>
</table>
So that the average quantity of phosphate of lime in the several specimens is as follows:

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Phosphate of lime (inorganic)</th>
<th>Potash (inorganic)</th>
<th>Phosphate of lime (soluble)</th>
<th>Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peruvian</td>
<td>25-12</td>
<td>31-50</td>
<td>32-25</td>
<td>15-66</td>
</tr>
<tr>
<td>Angamos</td>
<td>26-25</td>
<td>31-50</td>
<td>25-12</td>
<td>15-66</td>
</tr>
<tr>
<td>Ichaboe</td>
<td>31-50</td>
<td>31-50</td>
<td>25-12</td>
<td>15-66</td>
</tr>
<tr>
<td>Patagonian</td>
<td>47-4</td>
<td>47-4</td>
<td>47-4</td>
<td>47-4</td>
</tr>
<tr>
<td>Salannah Bay</td>
<td>55-84</td>
<td>55-84</td>
<td>55-84</td>
<td>55-84</td>
</tr>
<tr>
<td>Kooria</td>
<td>14-75</td>
<td>14-75</td>
<td>14-75</td>
<td>14-75</td>
</tr>
<tr>
<td>Moorua</td>
<td>16-05</td>
<td>16-05</td>
<td>16-05</td>
<td>16-05</td>
</tr>
</tbody>
</table>

These facts are very suggestive as showing how guano, by exposure to air and moisture, has the ammonical salts washed out, at the same time, as a consequence, increasing the ratio of phosphates.

Organic Matter.—The amount of organic matter in guano, other than ammonia and its salts, is of no great importance in estimating its value as a manure. Not unfrequently the amount of organic matter, containing uric acid or ammoniacal salts, is stated in analyses, as organic matter “rich in” or “containing ammonia,” but it is obvious such analyses are nearly worthless, the value of the guano depending essentially on the quantity of nitro-gen, either existing as ammoniacal salts or capable of being converted into them. Good guano contains on an average about 50 per cent. of ash (mineral matters) and 50 per cent. of combustible (organic) matters.

Sand.—The knowledge of the proportion of sand in a guano is of some importance as determining its purity or otherwise. It is easy to understand how a deposit like guano, existing often near the sea-shore, and frequently on a sandy soil, should contain a certain admixture of sand. Some specimens are almost free from it, and few genuine specimens contain more than 1 to 2 per cent.

Common Salt.—The presence of common salt in a guano need not surprise us. It is doubtless derived from the sea, partly through the medium of the birds themselves, and partly from the evaporation of the salt spray continually driven upon the coasts by the wind. It is variable in quantity, as we should expect from a knowledge of its origin, ranging in samples of genuine guano from 1 to 5 per cent. Although common salt has been shown to possess a certain power of absorbing ammonia, yet this is but transient, and the efficacy of guano cannot be said to depend to any extent upon the sea salt present in it. The knowledge of its amount is of great importance, since the guano is not unfrequently adulterated with salt.

Water.—Obviously the larger the amount of water present in guano, the smaller will be the proportion of valuable constituents in a given weight. Genuine guano contains on an average from 10 to about 20 per cent. of water. Many of the salts in guano are likewise deliquescent, so that it has a tendency to become moist by exposure to the air; and this tendency to absorb moisture is an element of value in the manure, especially in dry seasons.

Calculation of the money value of guano from the results of analyses.—In a most important and interesting paper “On the value of artificial manures,” Mr. Way arrives at certain money values for ammonia, phosphoric acid, and the various constituents of guano and other manures, by a comparison with the cost of these several compounds in their ordinary commercial salts. These numbers will be found most valuable to the agriculturist in drawing his own conclusions respecting the value of a guano or other manure from the results of analysis furnished to him by the chemist. They are as follows:

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Value per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>£256</td>
</tr>
<tr>
<td>Potash</td>
<td>31</td>
</tr>
<tr>
<td>Phosphate of lime (insoluble)</td>
<td>7</td>
</tr>
<tr>
<td>Phosphate of lime (soluble)</td>
<td>32</td>
</tr>
<tr>
<td>Organic matter</td>
<td>1</td>
</tr>
</tbody>
</table>

and the following example of their application may prove useful.

Calculation of the money value of guano, as deduced from the cost of its several constituents in their commercial salts, applied to the mean composition of Peruvian guano deduced by Mr. Way from 78 analyses:

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Weight per ton</th>
<th>Cost per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>16-5</td>
<td>£930</td>
</tr>
<tr>
<td>Organic matter</td>
<td>52-0</td>
<td>1</td>
</tr>
<tr>
<td>Potash</td>
<td>3-5</td>
<td>108</td>
</tr>
<tr>
<td>Insoluble phosphate of lime</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Soluble phosphate of lime</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

Value of 100 tons = £1,475

Or per ton = £14 15 0

* A. B. Noroeota, on the Function of Salt in Agriculture, Phil. Mag. n. 179.
† Agricultural Journal, xvi. 503.
Hence it is obvious that whilst guano was selling at £11 per ton, it was more economical and convenient to employ it than to make an artificial mixture of its chemical constituents; but now that the price has risen to about £14 per ton, it becomes a question whether it will not be possible to produce an artificial compound having equal value as a manure which will compete in price with the guano.

Inquiries and Adulterations.—In consequence of the high price of guano, the great demand for it, and the case with which the unwary farmer may be imposed upon, guano is adulterated with various substances, and to a great extent. Impositions even have been practised by selling as genuine guano artificial mixtures, made to look so much like guano that the farmer would scarcely detect it. The writer recollects examining a guano which contained 50 per cent. of sand, and no less than 25 per cent. of sea salt; and Dr. Ure gives the following analysis of an article sent to him, which had been offered to the public by advertisement as Peruvian guano which contained—

<table>
<thead>
<tr>
<th>Substance</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common salt</td>
<td>32·0</td>
</tr>
<tr>
<td>Sand</td>
<td>28·0</td>
</tr>
<tr>
<td>Sulphate of iron</td>
<td>5·2</td>
</tr>
<tr>
<td>Phosphate of lime</td>
<td>4·0</td>
</tr>
<tr>
<td>Organic matter (from bad guano to give it smell)</td>
<td>23·3</td>
</tr>
<tr>
<td>Moisture</td>
<td>7·5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100·0</strong></td>
</tr>
</tbody>
</table>

In fact, so numerous and various are the tricks played with guano, that unless a sample is submitted to a skilful chemist for analysis before purchase, we would strongly recommend the agriculturist to purchase of no one but dealers of unquestionable honor.

Professor Johnstone observes: "Four vessels recently sailed hence for guano stations, ballasted with gypsum, or plaster of Paris. This substance is intended for admixture with guano, and will enable the parties to deliver from the vessel a nice-looking and light-colored article. The favorite material for adulterating guano at the present moment, isumber, which is brought from Anglesea in large quantities. The rate of admixture is, we are informed, about 15 cwt. ofumber to about 5 cwt. of Peruvian guano, from which an excellent-looking article, called African guano, is manufactured."

**GUN COTTON. (Syn. Pyrocelite; Palmitocoton, Fr.)** In 1833 M. Bracoonot discovered that starch, by the action of monohydrated nitric acid, became converted into a peculiar substance which dissolved in excess of the acid, and was reprecipitated in a granular state on the addition of water. This substance, known as xylodine, when washed and dried, was found to explode on contact of a light, and even if heated to 356°. It also exploded if subjected to a smart blow. The subsequent researches of M. Pelouze indicated this singular body to be starch, C_{6}H_{10}O_{5}, in which one equivalent of hydrogen is replaced by peroxide of nitrogen, or hyponitritic acid. The formula of xylodine would consequently be C_{6}H_{10}O_{5} trapped. On the supposition of this being the correct formula, 100 parts of starch should yield 127·7 parts of xylodine, and M. Pelouze obtained from 128 to 130. About thirteen years subsequently to the discovery of xylodine, M. Schönbein announced his discovery of gun cotton. Chemists immediately saw the analogy between the two substances, for while xylodine appears to be derived from starch by the substitution of one equivalent of hyponitritic acid for one of hydrogen, gun cotton is derived from cellulose (C_{6}H_{10}O_{5})_{n}, isomeric with starch) by the substitution of two or three equivalents of hyponitritic acid for the same number of equivalents of hydrogen.

**Preparation.**—Gun cotton can be prepared in several ways. The most simple consists in immersing, for a few seconds, well-carded cotton in a mixture of equal parts by volume of oil of vitriol of the specific gravity 1·845, and nitric acid of the specific gravity 1·500. The cotton, when well saturated, is to be removed; and, after being squeezed to repel as much as possible of the excess of adhering acid, well washed in clean cold water. As soon as the water no longer reddens litmus paper, the washing may be considered sufficient. The gun cotton thus prepared is cautiously dried at a heat not exceeding 212°. It is safer to dry at about 150°. The cotton prepared by this means explodes well, but does not always dissolve easily in ether. If, consequently, it is desired to prepare a very soluble cottow for photographic collodion, the following process may be employed, in which, instead of nitric acid, dry nitre is used.

- 4½ ounces pure dry nitre in fine powder.
- 30 drams (fluid measure) sulphuric acid, sp. gr. 1·845.
- 120 grains of well-carded cotton.

The cotton is to be well pulled out and immersed in the mixture of the nitre and sulphuric acid. The contact with the acid, &c., is to be insured by stirring and pulling out the cotton with two glass rods. As soon as perfect saturation is effected, which, with good management, will be in about one minute, the cotton is to be thrown into a large pan of
water and well raised. The vessel is to be continued under a tap until litmus paper is no longer reddened. The cotton is to be squeezed in the folds of a clean towel, and exposed (after being again well pulled out) to a gentle heat to dry. It is curious that the most soluble cotton is often the least explosive, although there is reason to believe that the most soluble cotton is that which nearest approaches in constitution to tri-nitro cellulose.

M. Schönbein recommends a mixture of one measure of nitric acid with three measures of sulphuric acid as the best bath for the cotton. The liquid is to be allowed to cool previous to its immersion. He also saturates the cotton with nitrate of potash, by immersing it in a solution of that salt before drying. Cotton prepared in this manner is not adapted for photographic purposes, but it is highly explosive, and, therefore, well fitted for blasting rocks.

The true constitution of gun cotton is by no means well established. It appears to be very liable to differ in composition according to the method of preparation. According to M. Béchamp it is essential, in order to obtain a cotton both fulminating and soluble in ether, to operate upon the mixture of nitre and sulphuric acid before the temperature (which rises on the ingredients being mingled) has fallen. If cooling has taken place previous to the immersion of the cotton, the resulting pyroxiline is fulminating, but insoluble in ether.

The analyses of MM. Donon and Ménard, and also of M. Béchamp, agree best with bi-nitro cellulose, while those of Gladstone, Vanekreff, and Reuter, Schmidt and Hecker and Pelouze are more in accordance with a tri-nitro cellulose. To add to the difficulty of forming a conclusion on the subject, M. Peligot's analysis agrees best with the expression \(\text{C}_9\text{H}_8\text{O}_4\), which is that of bi-nitro glucose.

According to M. Béchamp xyloidine and pyroxline are acted on by protocateue of iron, and the original substance being regenerated. Thus xyloidine affords starch, and pyroxline cotton. The regenerated cotton was analyzed with the following result:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>43.35</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>6.31</td>
</tr>
<tr>
<td>Oxygen</td>
<td>50.34</td>
</tr>
</tbody>
</table>

Explosive substances analogous to gun cotton may be prepared from many organic bodies of the cellulose kind, by immersing them in the same bath as for gun cotton. Among these may be mentioned paper, tow, sawdust, and calico.

When collodion is wanted for an application to cut surfaces, and the cotton is with difficulty soluble in alcoholic ether, a solution may easily be obtained if the cotton be first moistened with acetic ether and the alcoholic ether be afterwards added.

Several of the nitro-derivatives of starch and cellulose undergo spontaneous decomposition when kept for some time in stopped bottles.—(Gladstone.)—C. G. W.

GUNNERY. Under the head of Artillery, we have included nearly every point with which it appears necessary to deal in a work of this description. It is convenient, however, to say a few words in this place of Sir William Armstrong's gun. Instead of being cast like ordinary cannon, or formed of several longitudinal pieces like the Whitworth cannon, or of a looped or wire-bound tube, as proposed by Captain Blakely, Mr. Mallet, and others, the new gun is formed of an internal steel tube, bound over with strips of rolled iron, laid on spirally, somewhat after the fashion of small-arm barrels, the alternate strips being laid in opposite directions, so that the joints may cross each other, or, in other words, so as to "break joint." This system of construction is, of course, expensive, but it gives great strength with a very small quantity of metal. The internal steel tube is rifled in a very peculiar manner. Instead of having two, three, or four grooves, like ordinary rifled guns, or being formed with an oval bore like that employed by Mr. Lancaster, or with a polygonal bore, as in the Whitworth system, it has a very large number of small grooves close to each other, no less than 40, we believe, in a gun of 2½ inches bore. The slot or shell Mr. Armstrong usually makes of cast iron, of about three diameters in length, and covers it entirely over with thin lead, so that it may readily conform itself to the rifled interior of the bore when forced forward by the explosion of the charge. Provision for loading the gun at the breech is made by cutting a slot near the breech end down from the upper side into the bore, of a sufficient length to admit the elongated projectile and the charge of powder, and of a breadth slightly greater than the diameter of the bore. The bore itself is also slightly enlarged where it opens into the space formed by cutting out the slot, in order that the projectile and powder, after being lowered into the slot, may be more easily pressed forward by hand or other means into the bore. In order to close the space formed by the slot after the gun is charged, a movable breech-piece is formed to fit into it, and is furnished with two handles, by means of which it may be lifted out or dropped into its place as required. The breech-piece has fitted to its front face a facet of copper, a por-
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dition of which projects slightly, so as to form a disc which, when the breech-piece is forced a little forward, will enter the bore behind the charge, and by its expansion, at the moment of explosion prevent all escape of gas. The slight forcing forward of the breech-piece is effected by means of a strong screw passing in through the extreme breech end of the gun, and pressing against the rear end of the breech-piece. This screw is turned by a hand lever. The fore end of the breech-piece is bored out at the centre, the bore extending through the copper disc, and into this bore is placed, at the time of loading, a small charging cartridge. The "touch-hole," or hole for the detonating plug, is formed in the breech-piece, passing down from its upper side into its bore; so that when the piece is to be discharged, the detonating cap or plug is struck, the small discharging cartridge is thereby fired, and its fire is instantaneously communicated to the main cartridge in the bore of the gun itself. With his shells Mr. Armstrong uses a percussion fuse of his invention for causing the shell to burst on striking an object, in case the striking takes place before the time-fuze has operated. In a cylindrical case within the shell Mr. Armstrong fixes a weight or striker, by means of a pin passing through it and the sides of the case. This pin is cut or broken by the shock which the projectile receives in the gun at the instant of firing, and the striker, being thus liberated, recedes to the rear end of the case, and there remains until the velocity of the shell is checked by coming into contact with some object. When this takes place, the striker, not participating in the retardation of the shell, advances in the case, and causes a patch of detonating composition to be carried suddenly against a fixed point, which fires the composition and ignites the bursting charge in the shell. The system, having that a 32-pounder gun, constructed upon Mr. Armstrong's system, has a greater range and fires with greater accuracy than any gun at present in use in the navy; and yet, while the former weighs but 26 cwt., the present weighs no less than 93 cwt. We may therefore at once reduce the weight of our naval guns by nearly three-fourths, without impairing their range or aim. This would enormously increase the facility of handling them, and therefore leave us free to greatly reduce the number of men employed to work them. Again, with the breech-loading arm it would probably be found possible to get rid of the running out and in of the gun while in action, by counteracting the recoil in some suitable way; and for this reason, also, the number of men required to work them might be very much below the present staff. Again, both the bore and the thickness of the metal of the gun being greatly reduced, the external diameter of the gun will be so small that very small ports only would be necessary, and this would add materially to the safety of the gunners, especially in close action. Another advantage might be gained in the use of certain guns, particularly the bow-chase guns, on board ship. It is always a matter of great difficulty to give such a form to the ship that the muzzles of these may, when the guns are run out, project sufficiently far to carry the fire of the explosion clear of the vessel. With the long, slight Armstrong guns this difficulty would not be experienced.

GUNPOWDER. The discovery of gunpowder has been claimed for Roger Bacon and Schwartz. The ground for this appears to be no more than this: In their writings the earliest recorded mention of the discovery is made in any European language. Roger Bacon, unquestionably antecedent to his German rival, was born 1224, and died 1292; and his work, "De Nullitate Magie," appears to have been written about 1270, while Kircher's account gives 1354 as the date of the discovery by Schwartz. It appears, however, that an Arabic manuscript exists in the collection of the Escurial, which unmistakably describes gunpowder and its properties, the date of which is anterior to 1290.—Mallet.

This well-known composition is employed for charging the numerous varieties of fire-arms that, at the moment of ignition, violent definition, violent explosion, and an explosive force, the gas produced by the explosion of good gunpowder occupies nearly 900 times the volume of the powder itself; but, owing to the high temperature, the space occupied by the gas at the moment of formation, is probably nearly 5,700 times greater than the volume of the powder. One of the most popular errors, regarding the projectile force of explosive substances, arises from the extremely vague meaning generally attached to the words strong, powerful, and other equivalent terms. It is this which leads so many to imagine the possibility of attaining marvellously long ranges by means of the various fulminating substances known to chemists. The latter are unfit for use in fire-arms, owing to a variety of circumstances. One of them is the extreme rapidity of their explosion. The whole mass appears to be converted into gas at once, whereas in gunpowder the ignition proceeds from particle to particle. The action of fulminates is also too local; if a portion of any of the more violently explosive substances be fired on a piece of metal, the latter will be perforated or depressed exactly at the spot occupied by the substance, and if it be attempted to use it to charge fire-arms, they will be destroyed, and yet, in all probability, the bullet not perforated. Moreover, the impetus of the explosion fails to use fulminates successfully for charging shells, because the latter, instead of being blown to pieces of moderate size, capable of inflicting

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large wounds and throwing down buildings, become converted into fragments so small as to be far less destructive. The escape of the Emperor of the French, from a recent attempt at his assassination, was probably owing to this circumstance.

It has been found that no composition fulfils so many requisites for charging fire-arms as a mixture, in due proportions, of sulphur, nitre, and charcoal. It is this composition, which, in the form of small grains, more or less polished, constitutes gunpowder. The latter should possess several properties which, although sometimes tending in opposite directions, are not entirely incompatible, and may therefore be nearly attained in practice. Some of the principal of these are the following: 1. The proportions should be so adjusted that the combustion may be complete, and little residue be left after explosion. 2. The powder should be as little hygroscopic as possible. 3. It should be sufficiently, but not too explosive. 4. It should be hard and dense enough to bear carriage without breakage of the grains.

Too great a proportion of carbon and sulphur will cause rapid fouling of the gun, and the explosive force will be less than it should be; too small a proportion of sulphur will render the powder too hygroscopic. The presence of soda or chloride of potassium in the nitre will lead to the same fault. The powder must be sufficiently stamped, or it will not possess the fourth requisite.

The history of gunpowder may be conveniently studied under the following heads:—
Preparation of the ingredients.
Mixtures and granulation.
Modes of estimating projectile force.
Analysis of gunpowder.

**Preparation of the ingredients.**

*Preparation of the nitre.*—The nitre employed for powder is always in a state of almost absolute purity, especially as regards the presence of the chlorides of potassium or sodium. The crude nitre of commerce contains several impurities, among which are found nitrates of soda and lime, chlorides of potassium and sodium, and sulphates of potash and soda. They are all removed by crystallization. The principal impurity is common salt. The process of purification is founded on the fact that the latter substance is almost equally soluble in hot or cold water, whereas nitre is far more soluble in hot than in cold water. The following is the French mode of refining saltpetre: 1,200 kilograms are gently heated with 600 litres of water in a copper boiler. The solution is constantly stirred and skimmed, and more nitre is added, until the total quantity is 3,000 kilograms. As soon as the whole is added, and it is presumed that all the nitre is dissolved, the common salt is removed from the bottom of the boiler. The solution is now to be clarified with glue. For this purpose 400 litres of water are added by small portions, and then 1 kilogramme of the glue dissolved in hot water. The scum, which soon rises, is removed, and the fluid is boiled until clear. The whole is then allowed to cool to about 194°, and the solution of nitre is carefully decanted from the layer of common salt into the crystallizing vessel. The latter is a large shallow pan with sloping sides. The fluid is constantly stirred as it cools, in order that the crystals formed may be very small; this is done in order to facilitate the washing process, and also because the fine powdery crystals are well adapted for admixture with the other ingredients. When the crystallizing solution is cold, the nitre is removed to boxes containing false bottoms, pierced with holes. The aperture in the bottom of the box (below the false bottom) being closed, a saturated solution of pure nitre is poured on the crystals to dissolve out the chloride of sodium. Being already saturated, it is evident it cannot dissolve any of the nitre. After remaining two hours in contact with the nitre, the solution is allowed to run off, and when the dropping has almost entirely ceased, the process of washing is repeated, substituting pure water for the solution of nitre. The product is dried at a gentle heat, being constantly stirred to enable it to retain the pulverulent form. The power (above alluded to) possessed by a saturated solution of nitre, of dissolving other salts has been taken advantage of in one of the processes for analyzing saltpetre. Some manufacturers fuse the nitre after it has been purified by crystallization. This process has several disadvantages, among others that of necessitating machinery to reduce it again to a pulverulent state.

*Preparation of the sulphur.*—Sulphur may be purified for the gunpowder-maker by two processes. In the first the crude article is fused in an iron pot, so contrived that the fire does not play directly on the bottom, but only round its sides. The lighter impurities are to be removed by skimming, while the heavier sink to the bottom. The temperature should not be allowed to rise much above 232°, for it then becomes sluggish, and at 320° it is so thick as to prevent the impurities from being removed.

Sulphur may be more readily and economically purified by distillation. The apparatus for the purpose is exceedingly simple in principle; but the process requires care, and is not entirely free from danger. As it is not intended to obtain the sulphur in the state of flowers, the apparatus for condensation is not required to be kept cold; in fact, the still is purposely placed so near to the chamber of condensation, that the sulphur may be received.
GUNPOWDER.

in the fluid state. There are several points which must be attended to in the construction of an apparatus for the distillation of sulphur; they are as follows: 1. The crude sulphur must be capable of being introduced, and the refined product removed easily, without air being, at the same time, permitted to enter the still or condenser. 2. Free means of egress for the heated air must be provided. 3. The contrivance for the latter purpose must not allow fresh air to return. 4. The process must be continuous. The still and condenser employed in France for the purification of crude sulphur fulfills all these conditions. The still is in the form of a very wide-necked tubulated retort, made of cast iron. It is set in brickwork over a furnace, and opens into a square brick chamber surmounted by a dome. The latter has a rather short chimney over it, containing a valve opening upwards to permit escape of the heated air, but not allowing any thing to return. Over what may be termed the tububrature of the retort or still, is placed an iron pot with a tube communicating with it. The pot is heated by the same fire that works the still. The crude sulphur is placed in the pot where it melts, and by raising a plug, which closes the tubulature, may be made to enter the still. The pipe forming the tubulature rises a short distance above the bottom of the iron supply pot. This is in order that any heavy mechanical impurities may sink to the bottom, and not enter the still, and unnecessarily clog it. If the pot be always kept full of melted sulphur, and the latter is permitted to enter by raising the plug, it is evident that no air will find its way into either the retort or condenser. It is exceedingly important that this should be the case, because violent explosions are liable to occur if the highly heated vapor of sulphur comes in contact with an oxidizing medium, such as atmospheric air, which would convert it into sulphurous acid. The melted sulphur which collects on the floor of the chamber is allowed to flow out when desired, by means of an iron plug attached to a rod of the same metal. The sulphur is not allowed to run out entirely, so as to permit air to enter, for the reasons stated above. The loss occurring during the purification is owing partly to oxidation, resulting in the formation of sulphurous acid, and partly to the fixed impurities contained in the crude material.

Preparation of the charcoal.—Of the three ingredients of gunpowder, the most important is generally considered to be the charcoal. Unfortunately the woods which are best adapted for the production of pyroigneous acid, are not fitted for the manufacture of gunpowder; the charcoal must, therefore, be prepared specially. The following are the essential properties of good charcoal for powder: 1. It should be light and porous. 2. It should yield little ashes. 3. It should contain little moisture. The woods yielding good powder charcoals are black alder, poplar, spindle tree, black dogwood, and chestnut. Hemp stalks are said to yield good charcoal for gunpowder. The operation of preparing the charcoal naturally divides itself into three processes. 1. The selection of the wood. 2. Preparation of the wood previous to carbonization. 3. The carbonization.

In selecting the wood care is to be taken to avoid the old branches, as the charcoal made from them would yield too much ashes. The bark is to be rejected for the same reason. The wood is to be cut into pieces from 4 to 6 feet long. If the branches used are more than 4 of an inch in diameter they are to be split. If the wood be too large, great difficulty will be found in uniformly charring it.

There are two methods employed in the charring of wood for gunpowder. In one, the operation is conducted in pits; but the process more commonly resorted to is distillation in cylindrical iron retorts. There are certain advantages in the pit process, but they are more than counterbalanced by the convenience and economy of distillation. The retorts used are about 6 feet long, and 2 feet 9 inches in diameter. The ends of the cylinders are closed by iron plates, placed to admit tubes of the same metal. Some of the latter are for the introduction during the carbonization of sticks of wood, which are capable of being removed to indicate the stage of the decomposition, while another communicates with the condenser. The more freely the volatile matters are allowed to escape, the better the quality of the resulting charcoal. If care be not taken in this respect, especially as the distillation reaches its close, the tarry matters become decomposed, and a hard coating of carbon is deposited on the charcoal, which greatly lowers its quality. The process of burning in pits is considered to yield a superior coal, owing to the facility with which the gases and vapors fly off.

The degree to which the burning or distillation is carried materially influences the nature of the resulting powder. If the operation be arrested before the charcoal becomes quite black, so that it may retain a dark-brownish hue, the powder will be more explosive than it would be if it were pushed until the charcoal had attained a deep black color. When it has been found that no more volatile products are being given off, the fire is damped, and in a few hours the contents of the cylinders are transferred to well-closed iron boxes to cool.

Mixtures and Granulation.

A very considerable number of methods have been employed at various times, for effecting that thorough incorporation of the ingredients necessary for the production of a good powder. The oldest method consists in stamping the materials in wooden mortars. The
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pestles are square shafts of wood ending in brass beaters. The mortars are of wood, and so shaped that any of the composition which may be forced upwards by the blows of the stampers falls back to the bottom. In order to prevent fracture of the mortars, a piece of wood of the toughest kind should be let in on the spot where the pestle falls. The pestles are raised by means of pegs fixed on a shaft, driven by a water-wheel or steam-engine.

One of the many methods adopted to mix the nitre, sulphur, and charcoal, is by means of drums containing metallic balls; but this arrangement is inferior to that where edge stones are employed. This last is superior to all others, the product being not only very dense, and, therefore, capable of enduring, without becoming pulverulent, the motion unavoidable in carrying it about, but it is also thoroughly incorporated. It is, of course, essential that the stones, and the bed on which they work, should not strike fire during work.

To secure this, they are sometimes made of calcareous stone, and sometimes of cast iron. Previous to being subjected to the action of the mill, the ingredients must be pulverized and mixed. The pulverization may conveniently be effected in wooden drums containing metallic balls. The pulverized materials, after being sifted or boiled, and weighed out in the proper proportion, are to be inserted in a mixing drum, containing on its inside pieces of wood projecting inwards, so that, as it revolves, complete admixture gradually takes place.

The product of the last operation is now ready to be laid on the bed of the mill. During the grinding, the cake is kept moist by the addition, at proper intervals, of enough water to make it cohesive. As the stones revolve, a scraper causes the material to take such a position that it cannot escape their action. The cake produced by the action of the stones is ready for grinding or coring. For this purpose the cake is subjected to powerful pressure, by means of a hydraulic press. The mass is then broken up and transferred to a species of sieve of skin or metal pierced with holes. A wooden flail is placed on the fragments, and the sieves are violently agitated by machinery. By this means the grains and dust produced by the operation fall through the holes in the skin or metal disks, and are afterwards separated by sifting. Sometimes the machinery is so arranged that the grinding and separation of the meal powder are effected at one operation. The meal powder is reworked, so as to convert it into grains. The next operation to which the powder is subjected is grinding. Its object is to render it less liable to injury by absorption of moisture or disintegration during its carriage from place to place. The grinding is effected by causing the ground powder to rotate for some time in a wooden drum or cylinder, containing rods of wood running from end to end. The grains, as they rub against each other, and against the wooden ribs, have their angles and asperities rubbed off, and at the same time the surface becomes harder and polished. It is finally dried by exposure to a stream of air, heated by means of steam.

A vast number of experiments have been made, at various times, to discover the proportions of nitre, sulphur, and charcoal best adapted for the production of gunpowder. It has been found, as might have been anticipated, that no general rule can be given, no admixture can be made which shall suit every requirement. Those powders which contain the largest quantities of charcoal are, it is true, as powerful as others in projectile force, but they have the disadvantage of attracting more humidity from the air. It is very singular that all nations appear to have found, by trial, the proportions most generally useful for ordinary purposes, and it is worthy of remark that they all approximate to the percentages required by the very simple formula, KO\textsubscript{3}N\textsubscript{2}S + S + 5C.

Modes of Estimating the Projectile Force of Gunpowder.

The usual mode of determining the propulsive force of powder is by ascertaining the distance to which it can throw a ball of known weight. The instrument used in this country for this purpose consists of an 8-inch mortar charged with 2 ounces of powder, the ball being, in each case, of the same size and weight. The French use for the purpose an iron mortar, elevated at an angle of 45°. The mortar is 7'5 inches in diameter. The ball is of bronze, and is only 0'067 inches smaller than the bore of the gun; the windage is, consequently, very small. The charge of powder being 3'2 ounces, and the weight of the ball 63 lbs., the latter should be thrown not less than 437'5 yards.

The force of powder may also be estimated by means of an instrument called a pendulum gun. It consists of a gun barrel hung at the lower end of a pendulum, so arranged that the amount of angular deviation caused by the recoil may be measured; the balls may also be fired into a cup suspended to a similar pendulum. The data obtained serve to enable the rapidity of motion of the ball, at the moment of discharge, to be calculated by means of formulae contrived for the purpose.

On the Analysis of Gunpowder.

Several methods have been given by various chemists for the analysis of gunpowder; the following, on the whole, appears the most effective: The percentage of water is, in the first place, to be determined, by drying in vacuo over sulphuric acid, until no more diminution of weight occurs. The dried powder, or a fresh quantity, is then to be washed on a filter with boiling water, until nothing more is dissolved out. The residue is to be dried below 212° and weighed; the loss is the nitre. If preferred, the solution of the nitre may
be evaporated to dryness, and the residue weighed. The mixture of charcoal and sulphur is then to be digested in a stoppered flask with bisulphide of carbon; this will dissolve out the sulphur and leave the charcoal. The loss of weight of the dry mixture of sulphur and charcoal will enable the percentages of charcoal and sulphur to be calculated. If it be desired to know the quality of the charcoal, a combustion of it may be made with a mixture of chromate of lead and bichromate of potash. Ordinary charcoal contains from 60 to 74\% of carbon, 8\% to 11\% hydrogen, 0\% to 3\% per cent. ashes. It has been attempted to dissolve out the sulphur with sulphite of soda or caustic potash; but these methods involve several sources of error.

Good gunpowder should not lose more than 1 per cent. of moisture on drying. It should not leave alkaline globules when exploded on a clean metallic plate. The specific gravity of a good powder should not be less than 1.7\%; it is sometimes as high as 1.846. The denser the powder the better it endures transportation. As the density cannot be taken in water, owing to the solubility of the nitre, turpentine or benzole must be substituted, a correction being made for the difference in density of the fluid medium.—C. G. W.

GUTTA PERCHA. In 1848 Dr. Faraday drew the attention of experimentalists to the highly insulating power of gutta percha, which not only possesses this property under ordinary circumstances, but likewise retains it under atmospheric conditions which would make the surface of glass a good conductor. This has led to its almost universal adoption as the insulator for the wires of the electrical telegraph. When buried in the earth, unless it is attacked by insects, or by a fungus, it retains its high insulatory power, and we have every reason for believing that gutta percha does not undergo a change when immersed in sea water. It has, however, been found, that when it has been exposed to the intense sunshine of India, it undergoes a remarkable change; oxygen is absorbed, the gutta percha loses its coherence, and at the same time its powers of insulation.

II

HARDENING. The process by which metals are rendered harder than they are when they first leave the hands of the workman.

Some metals are hardened by hammering or rolling; but care is required not to carry this too far, as brittleness may be induced. Sudden cooling is had recourse to with some metals. Pure hammered iron appears, after annealing, to be equally soft, whether suddenly or slowly cooled; some of the impure kinds of malleable iron harden by immersion. Steel, however, receives by sudden cooling that extreme degree of hardness combined with tenacity, which places it so incautiously beyond every other material for the manufacture of cutting tools.

In hardening and tempering steel, there are three things to be considered, namely, the means of heating the objects to redness, the means of cooling the same, and the means of applying the heat for tempering, or "letting them down." It is not possible in this work to enter into the manipulative details of hardening steel for various purposes; the most valuable information on this subject is given in Holtzapffel's work on Turning and Mechanical Manipulation.

Steel pens are hardened by being heated in large quantities in iron trays within a furnace, and then plunged in an oily mixture; generally, they are likewise tempered in oil, or a composition, the boiling point of which is the same as the temperature suited to "letting them down."

Saws and springs are hardened in various compositions of oil, suet, wax, and other ingredients, "which, however, lose their hardening property after a few weeks' constant use." Steel plates are hardened occasionally by allowing water to fall on them when hot.

Case hardening is the process by which wrought iron is first converted exteriorly into steel, and is subsequently hardened to that particular depth, leaving the central parts in their original condition of soft and fibrous iron. The principal agents used for case hardening are animal matters, as the hoofs, horns, bones, and skins of animals. The prussiate of potash, which is a compound of carbou and nitrogen, is also employed for case hardening. In principle it is the same as the animal substances. The iron is heated in the open fire to a dull red, and the prussiate is either sprinkled upon it or rubbed on in the lump; it is returned to the fire for a few minutes, and immersed in water. In the volume of Lardner's "Cyclopedia," on Iron and Steel, edited by Robert Hunt, the subjects of hardening and tempering are treated in a practical manner.

HEAT. The Force or Principle upon which the conditions, relatively, of solid, fluid, and gaseous states depend. That which produces the sensation of warmth.

The discussion of the habits of heat with the different kinds of matter belongs to physical-chemical science, and will be treated of in Ure's Dictionary of Chemistry. It will suffice in this place to state succinctly those laws which have, more directly, a bearing on any of our manufacturing processes.
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Heat and motive power are mutually convertible, and heat requires for its production, and produces by its disappearance, motive power in the proportion of 772 foot-pounds for each Fahrenheit unit of heat.—Rankine.

This unit of heat has been established by Dr. Joule to be the amount of heat required to raise the temperature of one pound of liquid water by one degree of Fahrenheit. A falling weight, or any other mode of motion, produces a definite quantity of heat according to this law.

If the total actual heat of a homogeneous and uniformly hot substance be conceived to be divided into any numbers of equal parts, the effect of those parts in causing work to be performed will be equal.—Rankine.

Or, in other words, of a given equivalent of heat, from whatever source produced, the work which it can effect is always an equal and constant quantity.

Heat may be produced by friction, as we see in the development of it, powerfully, in the axles of railway carriages, insufficiently lubricated. By the attrition of two pieces of wood ignition can be obtained.

Heat is developed in the mixture of bodies of different densities, such as spirits of wine and water, or sulphuric acid and water, there being a diminution of volume in each case.

Heat is produced by many conditions of chemical combination, in numerous cases so energetically as to produce intense combustion and even explosion.

Heat is obtained by combustion for our ordinary manufacturing processes and domestic uses. This is a chemical union of one body with another, as carbon with oxygen; but to effect this an excitant appears necessary, or a continually increasing excitement of the energy upon which heat depends, as the application of flame in one case, and the phenomena of spontaneous combustion in another.

Electricity, by its disturbing power, develops heat; and this all-important force is also rendered manifest by the processes of vitality, (vital or nervous forces.)

Dr. Joule has clearly shown that, whatever may be the source of heat, a certain fixed elevation of temperature is produced by a given amount of mechanical, chemical, electrical, or vital disturbance, and that the mechanical value of the cause producing the heat is exactly represented by the mechanical effect obtained.

For a full discussion of this important point, see the Memoirs of Joule, of Thomson, and of Rankine, in the Philosophical Transactions of London and Edinburgh. The applications of heat will be found under the proper heads.

HELIOGRAHY was the name given by M. Niepce to his process for obtaining, through the agency of the solar rays upon plates of metal or glass covered with resin, the impressions of external objects. The process has been employed of late years in preparing lithographic stones, and steel or copper plates, for receiving photographic impressions, which might be subsequently printed from. The name heliography is a far more appropriate one than photography; but the latter has become too permanently fixed in our language to leave any hope of our returning to the former.

HEMATITE (Fre Oblige, Fr.; Rothenstein, Germ.) is a native reddish-brown peroxide of iron. This term was applied to this ore of iron by the ancients on account of the red color of the powder, from οξα, blood.

This species includes specular iron and the old red iron ore. "The varieties of a submetallic or non-metallic lustre were included under the names of red hematite, fuxion red iron, or of soft and earthy red ochre, and when consisting of slightly coherent scales, sealy red iron or red iron froth."—(Dana.) Dana also includes, most injudiciously as it appears, reddle or red shale, and Jasper clay iron ore, with some others, among the hematomas.

HENBANE. The Hyoscyamus Niger. Henbane is a plant used in medicine, from which modern chemistry has extracted a new crystalline vegetable principle called hyoscine, which is very poisonous, and when applied in solution to the eye, determines a remarkable dilatation of the pupil, as belladonna also does.

HONES AND HONE SLATES. These are slatey stones which are used in straight pieces for sharpening tools after they have been ground on revolving grindstones. The more important varieties are the following:

The Norway Roystone, which is the coarsest variety of the hone slates, is imported in large quantities from Norway. In Charnwood Forest, near Mount Sorrel, in Leicestershire, particularly from the Whittle Hill quarry, are obtained the Charley Forest Stone, said to be one of the best substitutes for the Turkey olistone, and it is much in request by joiners and others. Age stone, Snake stone, and Scotch stone, are used especially for polishing copper plates. The Welsh olistone is almost in equal repute with the Charley Forest stone; it is obtained from the vicinity of Llwyd Idwall, near Snowdon, and hence it is sometimes called Idwall stone. From Snowdon is also obtained the cutler's green stone, The Derwshire olistones, obtained near Tavistock, which were introduced by Mr. John Taylor, are of excellent quality, but the supply of them being irregular they have fallen into disuse.

The German razor hone has been long celebrated. It is obtained from the slate mountains in the neighborhood of Ratisbon, where it occurs in the form of a yellow vein running
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through the blue slate, varying in thickness from 1 to 18 inches. When quarried it is sawn into thin slabs, and these are generally cemented to slices of slate, which serve as a support. Sometimes, however, the yellow and the blue slate are cut out naturally combined. There are several other hone stones, which, however, require no particular notice.

The Turkey oilstone is said to surpass in its way every other known substance, and it possesses in an eminent degree the property of abrading the hardest steel; it is, at the same time, of so compact and close a nature as to resist the pressure necessary for sharpening a graver, or any instrument of that description. There are white and black varieties of the Turkey oilstone, the black being the hardest, and it is imported in somewhat larger pieces than the white; they are found in the interior of Asia Minor, and are brought down to Smyrna for sale.

HORSE CHESTNUT. (Marronnier D'Inde, Fr.; Gewine Rosskastanie, Germ.)
The wood of this well-known tree is used by the Tunbridge turner. It is only employed for some large varnished works.

HORSESHOES. The ordinary method of making these is well known. There has, however, been lately introduced with much success a machine for making horseshoes. One of these machines has been erected at Chillington Ironworks, Wolverhampton, by the inventor, Mr. Henry Burden, of Troy, New York. As early as 1835 he took out a patent for a machine for making horseshoes, which he improved upon in 1843, and this was turned to practical account by the production of a considerable number of horseshoes. The present machine, however, which was patented in 1857, is entirely different from the former ones, and is a very remarkable piece of mechanism. In the previous machines the piece of iron bar of which the shoe was to be made was rolled into shape before being bent, and the pressure of the rollers being in the direction of it length, the bar, when it was pressed, was naturally rather extended in length than width, and the widening which is required at the crown of the shoe was not properly effected. By the present plan the bar, after being hoisted, enters the machine by a feeding apparatus, a piece of the required length is cut off, and, by a stroke from a piece of steel shaped like the inside of a horse-shoe, is bent, and falls upon a die on a wheel beneath, corresponding to one on a cylinder above, and thus acquires by pressure the desired shape, two lateral strikers at the same moment hitting the extremities, or heels, of the shoe, and driving them inwards into the required shape. Thence it passes between another pair of dies, where it is stamped and by an ingenious arrangement is flattened from the curled shape which the wheel gives it as it falls at the mouth of the machine. The shoes thus made are remarkable for their exactness in shape and in the position of the holes—a most important point with regard to the safety of horses' feet; and they can be produced, when the machine is in proper order, at the rate of 60 per minute, which is more than two men can forge in a day, and the superiority over shoes forged by hand is very striking. As the bar is bent before being pressed in the die, the pressure at the crown is in the direction of the width, and hence the widening is readily effected.

HYDRAULIC CRANES. The application of water-pressure to cranes is due to Sir Wm. Armstrong. These are now so generally applied, that although the subject belongs properly to engineering, it is thought advisable to include some notice of these valuable and interesting machines in this work. A statement made, by the request of the British Association in 1854, by the inventor himself, so completely explains all the peculiarities of these cranes, that the paper is reproduced from the Proceedings of the Association.

"The employment of water-pressure as a mechanical agent having recently undergone a great and rapid development, I may be permitted to make a few observations on the successive steps by which its present importance has been attained. In so doing I shall commence with the year 1840, in which, after many preliminary experiments, I succeeded in establishing, upon the public quay at Newcastle-upon-Tyne, the hydraulic crane which has formed the basis of what has since been effected.

"This crane both lifted the weight and swung round in either direction by the pressure of water, and was characterized, like all other hydraulic cranes since made, by remarkable precision and softness of movement, combined with great rapidity of action.

"The experiment thus made at Newcastle having proved satisfactory, I soon afterwards obtained authority, through the intervention of Mr. Hartley, the Dock Surveyor of Liverpool, to construct several cranes and hoists upon the same principle at the Albert Dock in that town, where they were accordingly erected, and have ever since continued in operation.

"The next place at which these cranes were adopted was Grimsby New Dock, where an important step in the advancement of this kind of machinery was made on the suggestion of Mr. Rendel, who pointed out its applicability to the opening and closing of dock gates and sluices, and instructed me to extend its application to those objects. An extensive system of water-pressure machinery was accordingly carried out at that dock, and the result afforded the first practical demonstration that the pressure of a column of water could be advantageously applied as a substitute for manual labor, not
merely for the cranage of goods, but also to give safe and rapid effect to those mechanical operations which are necessary for passing ships through the entrance of docks. At Newcastle and Liverpool the supply was derived from the pipes communicating with the town reservoirs, but at Grimsby a tower was built for supporting a tank into which water was pumped by a steam-engine. In the former cases, the fluctuation of pressure, consequent upon the variable draught from the pipes for the ordinary purpose of consumption, proved a serious disadvantage; but this objection had no existence at Grimsby, where the tank upon the tower furnished a separate source of power, undisturbed by any interfering conditions. Nothing could be more effectual for its purpose than this tower; but, in the natural course of improvement, I was subsequently led to the adoption of another form of artificial head, which possessed the advantage of being applicable, at a comparatively small cost, in all situations, and of lessening the size of the pipes and hydraulic machinery, by affording a pressure of greatly increased intensity.

"The apparatus thus substituted for a water tower I named 'the Accumulator,' from the circumstance of its accumulating the power exerted by the engine in charging it. The accumulator is, in fact, a reservoir giving pressure by load instead of by elevation, and its use, like that of every provision of this kind, is to equalize the strain upon the engine in cases where the quantity of power to be supplied is subject to great and sudden fluctuations.

"The construction of the accumulator is exhibited in fig. 327, and needs but little explanation. A, cylinder; B, plunger; c, c, loaded weight case; D, guides for ditto; E, pipe from pumping engine; F, pipe to hydraulic machine. It consists of a large cast-iron cylinder, fitted with a plunger, from which a loaded weight case is suspended, to give pressure to the water injected by the engine. The load upon the plunger is usually such as to produce a pressure in the cylinder equal to a column of 1,500 feet in elevation, and the apparatus is made sufficiently capacious to contain the largest quantity of water which can be drawn from it at once by the simultaneous action of all the hydraulic machines with which it is connected. Whenever the engine pumps more water into the accumulator than passes direct to the hydraulic machines, the loaded plunger rises and makes room in the cylinder for the surplus; but when, on the other hand, the supply from the engine is less, for the moment, than the quantity required, the plunger, with its load, descends and makes up the deficiency out of store.

"The accumulator also serves as a regulator to the engine; for when the loaded plunger rises to a certain height, it begins to close a throttle-valve in the steam-pipe, so as gradually to reduce the speed of the engine until the descent of the plunger again calls for an increased production of power.

"The introduction of the accumulator, which took place in the year 1851, gave a great impulse to the extension of water-pressure machinery, which is now either already applied, or in course of being applied, to the purpose of cranage throughout all the great dock establishments in London, as also to a considerable extent in Liverpool and other places. I have also applied it extensively to railway purposes, chiefly under the direction of Mr. Brunel, who has found a multitude of cases, involving lifting or tractive power, in which it may be made available. Most of these applications are well exemplified at the new station of the Great Western Railway Company in London, where the loading and unloading of trucks, the hoisting into warehouses, the lifting of loaded trucks from one level to another, the moving of turn-tables, and the hauling of trucks and traversing
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machines, are all performed, or about to be so, or means of hydraulic pressure supplied by one central steam-engine with connected accumulators. Mr. Rendel also, after having successfully adopted the low-pressure system to the working of the gates and shuttles at Grimsby, has since applied the high-pressure, or accumulator system, to the same purposes at other new docks, and a similar adaptation is being made by other eminent engineers at most of the new docks now in course of construction.

I have also adapted hydraulic machinery to the opening and closing of swing-bridges and draw-bridges of large dimensions; and, in fact, there is scarcely any mechanical operation to which human labor has been hitherto applied as a mere moving power, which may not be efficiently performed by means of water-pressure emanating from a steam-engine and accumulator. Even if hand labor be retained as the source of the power, the intervention of an accumulator will in many cases both economize labor and increase despatch. For example, a pair of heavy dock-gates requires the constant attendance of a considerable number of men, whose labor is only called into action occasionally, viz., when the gates are being opened or closed. Now, if an accumulator, charged by hand-pumps, were used, the labor employed would be constant, instead of occasional, and the power collected in the accumulator by the continuous process of pumping would be given out in a concentrated form, and thus the ultimate result would be effected with fewer hands and greater despatch than where manual labor is directly applied.

The form of pumping-engine which I generally use for charging the accumulator is represented in fig. 328. It consists of a horizontal steam-cylinder, with two force-pumps connected directly with the piston. These force-pumps are supplied with water from a cistern over the engine-room, into which the water discharged by the cranes is generally brought back by a return-pipe, so that the water is not wasted, but remains continuously in use.

With a pressure representing a column of 1,500 feet, the loss of head by friction in the pipes forms so small a deduction from the entire column as to be a matter of no consideration, and consequently the distance at which the engine may be situate from the points where the hydraulic machines may be placed, is of little importance, except as regards the cost of the pipe. It is advisable, however, if the pipe be very long, to apply an accumulator at each extremity, so as to charge the pipe from both ends.

With regard to the mechanism of hydraulic cranes, the arrangement which I first adopted, and have ever since adhered to, consists of one or more hydraulic presses, with a set of sheaves, used in the inverted order of blocks and pulleys, for the purpose of obtaining an extended motion in the chain from a comparatively short stroke of the piston. This construction, which characterizes nearly all the varieties of the hoisting and hauling machines to which I have applied hydraulic pressure, is exhibited in fig. 329, which represents one of these presses with sheaves attached, to multiply the motion four-fold. In cases where the resistance to be overcome varies very considerably, I generally employ three such cylinders, with rams or pistons acting either separately or conjointly upon the same set of multiplying sheaves, according to the amount of power required.

In hydraulic cranes the power is applied, not only for lifting the load, but also for swinging the jib, which latter object is effected by means of a rack or chain operating on the base of the movable part of the crane, and connected either with a cylinder and
piston having alternate motion, like that of a steam-engine, or with two presses applied to produce the same effect by alternate action.

"The absence of any sensible elasticity in water renders the motions resulting from its pressure capable of the most perfect control, by means of the valves which regulate the inlet and outlet passages of the machines; but this very property, which gives so much certainty of action, tends to cause shocks and strains to the machinery, by resisting the momentum acquired by the moving parts. Take, for example, the case of a hydraulic crane, swinging round with a load suspended on the jib, the motion being produced by the water entering on one side of a piston and escaping from the other. Under such circumstances, if the water-passages be suddenly closed by the regulating valve, it is obvious that the piston, impelled forward by the momentum of the loaded jib, but met by an unyielding body of water deprived of outlet, would be brought to rest so abruptly as to cause, in all probability, the breakage of the machine. So also, in lowering a heavy weight with considerable velocity, if the escape-passage be too suddenly closed, a similar risk of injury would arise from the abrupt stoppage of the weight, if a remedy were not provided; but these liabilities are effectually removed by applying, in connection with the water-passages to the cylinder, a small clack-valve, opening upwards against the pressure into the supply pipe, so as to permit the pent-up water in the cylinder to be pressed back into the pipe whenever it becomes exposed to a compressive force exceeding the pressure on the accumulator. By this means all jerks and concussions are avoided, and a perfect control over the movement of the machine is combined with great softness of action.

With regard to the kind of valves used for water-pressure machines, I find that either lift-valves or slide-valves may be effectually applied, and kept tight under heavy pressures, provided that sand be excluded from the water, and the valves be made of proper material.

In cases where a more prolonged movement is required than multiplying sheaves will conveniently afford, I employ rotative machines of various constructions. For heavy pressures, such as an accumulator affords, an arrangement consisting of three plungers, connected with a triple crank, and bearing a general resemblance to a three-throw plunger pump, is well adapted for the purpose. The admission and exhaust valves are miured spindles, pressed down by weights and levers, and lifted in proper rotation by cams fixed for that purpose upon a separate shaft; and these valves are associated with relief-clacks, to obviate the concussion which would otherwise be liable to take place at the turn of each stroke.

"The liability of water-pressure machinery to be deranged by frost has often been adduced as an objection to its use; and upon this point I may observe—first, that I have never experienced any interference from this cause when the machines were placed, as they generally are, beneath the surface of the ground, or within a building; and secondly, that when they are unavoidably exposed, all risk may be prevented by letting out the water in frosty weather whenever the machines cease working.

When the moving power consists of a natural column of water, the pressure rarely exceeds 250 or 300 feet, and in such cases I have employed for rotative action a pair of cylinders and pistons, with slide-valves, resembling in some degree those of a high-pressure engine, but having relief-valves, to prevent shock at the turn of the stroke. Fig. 390 shows a slide-valve adapted for the turning apparatus of a crane, but the relief-clacks of
HYDRIODIC ACID.

which are equally applicable to a water-pressure engine of the construction in question. Two of these clacks open against the pressure in the supply pipe, so as to afford an escape for the water, which would otherwise be shut up in the cylinder when the exhaust port closes, and the other two communicate with the discharge pipe, so as to draw in a portion of waste water to fill up the small vacancy which would otherwise be left in the cylinder on the closing of the admission port. A, supply pipe; B, exhaust pipe; C, pipes to cylinder; D, clacks opening against pressure; E, clacks opening from exhaust. About four years ago I constructed four hydraulic engines upon this principle at Mr. Beaumont's lead mines in Northumberland, at the instance of Mr. Sopwith, Mr. Beaumont's well-known agent, and two more have recently been added at the same place. They are used for crushing ore, for hoisting materials from the mines, for pumping water, and for driving a circular saw and other machinery. See Water-pressure Machinery, applied to mines.

"If in progress of time railways should be generally extended into mountainous districts, so as to render them accessible for manufacturing purposes, the rapid streams which abound in such localities will probably become valuable sources of motive power, and a wider field may then be afforded for the application of water-pressure engines to natural falls.

"The object, however, which I have chiefly had in view since I first gave attention to this subject, has been to provide in substitution of manual labor, a method of working a multiplicity of machines, intermittents in their action, and extending over a large area, by means of transmitted power produced by a steam-engine and accumulated at one central point. The common mode of communicating power by shifting could only be applied in cases where the machines were collected within a small compass, and where the accumulation of power necessary to meet varying resistance did not exceed that which a fly-wheel would afford. Compressed or exhausted air was almost equally inapplicable to the purpose I contemplated, in consequence of the many objections which its elasticity involves, as well as the liability to leakage, which, in an extended system of pipes and machines, requiring a multitude of joints, valves, and fitting surfaces, would form an insurmountable difficulty. But the use of water as a medium of transmission is free from all these objections, and its fitness for the purpose intended is now thoroughly established by the results which have been obtained."

HYDRIODIC ACID (Acide Hydriodique, Fr.; Hydriodsäure, Germ.) is an acid formed by the combination of 1/37 parts of iodine with 1 part of hydrogen by weight, and by measure equal volumes of iodine vapor and hydrogen combined without condensation. It is obtained pure and in the gaseous state by introducing into a glass tube, closed at one end, a little iodine, then a small quantity of roughly-powdered glass moistened with water, upon which a few grains of phosphorus, and lastly more glass; this mixture, iodine, glass, phosphorus, glass, is repeated until the tube is two-thirds filled. A cork and narrow bent tube are then fitted and gentle heat applied, when the hydriodic acid is liberated, and may be collected in dry bottles by the displacement of air. Another process is to place in a small retort 10 parts of iodide of potassium with 5 parts of water, add 20 parts of iodine, then drop in cautiously 1 part of phosphorus cut into small pieces, and apply a gentle heat; hydriodic acid will be formed abundantly, and may be collected as before stated. The following equation expresses the reaction:

\[ 2KI + \frac{1}{3}P + 8HO \rightarrow 2KO,HO,PO^4 + 7HI. \]

Hydriodic acid greatly resembles hydrochloric acid; it is colorless, and highly acid; it fumes in the air, and is very soluble in water. Its density is 4-3, and under strong pressure condenses to a yellowish liquid, which solidifies at 60° Fahr.

Hydriodic acid in solution is much more easily prepared, by suspending iodine in water, and passing a stream of washed hydrosulphuric acid through it until the color disappears; it is then heated to expel the hydrosulphuric acid, then allowed to rest, when it may be decanted from the precipitate of sulphur. The reaction consists simply in the displacement of the sulphur by the iodine, I₂S + I = III + S.

This liquid may be evaporated until it acquires a density of 1-7, when it consists of III + H₂O. It then distils at 262° Fahr. without decomposition. The solution cannot be long kept, being decomposed by the oxygen of the air with the liberation of iodine, which imparts a dark color to it. Chlorine decomposes it instantly, with liberation of the iodine.

The solution of hydriodic acid and of the iodides possesses the power of dissolving a considerable quantity of iodine, forming a dark solution.—II. K. B.
HYDROCYANIC ACID.

HYDROCYANIC ACID. Syn. Cyanhydric acid, Prussic acid, CNH₂. This highly important acid is regarded by all chemists as being formed on the exact type of the ordinary inorganic hydrazides, such as the hydrochloric or hydriodic. The compound radical analogous to chlorine, which is contained in it, has received the name of cyanogen, and possesses the formula CN. That this body is precisely analogous in its relations to the simple salt radicals is rendered certain by numerous facts. It combines directly with metals to form compounds; it possesses the same vapor volume, and unites with hydrogen to form a hydrazide, which in its turn decomposes the metallic oxides with formation of water. Thus, we have, with metallic oxides and hydrocyanic acid (M standing for a metal, MO + HCl=MCl + HO, and with hydrocyanic and metallic oxides, (Cy standing for cyanogen), MO + HICy =MCy + HO. Two volumes of chlorine and two of hydrogen yield four volumes of hydrochloric acid gas, and two volumes of cyanogen with two of hydrogen yield four volumes of hydrocyanic acid. The density of the vapor of hydrocyanic acid is consequently 0.9476. The theoretical number being 0.9442. Its density in the fluid state is 0.9971 at a temperature of 64° F. at ordinary pressures.

Hydrocyanic acid is never prepared in the anhydrous state, except as a curiosity, or for the purpose of scientific investigation. In fact it cannot be long preserved of great strength; a somewhat complex decomposition invariably taking place in it, with production of brown adhesive matters containing cyanide of ammonium, and also a substance by some considered to be an acid, and known as the azuline. Paracyanogen is probably formed at the same time. The constitution of azuline acid is by no means well known, and even its very existence, as a definite chemical substance, is doubtful. It is singular that the presence of a mineral acid greatly retards the decomposition of prussic acid, especially if it be dilute; the pharmacopeian acid consequently may be preserved of uniform strength, in well filled and closely stoppered bottles, for almost any length of time. The deadly nature of prussic acid unhappily causes it to be only too frequently resorted to by the despairing or the murderer. Fortunately, however, in spite of its volatility, the chemist possesses excellent means for its detection.

Preparation.—1. Hydromel acid. As prussic acid is largely employed in medicine, but in a very dilute form, it is usual to prepare it and dilute until of the proper degree of strength. The following process for preparing it will be found to give a satisfactory result and, moreover, it may be performed on any quantity of materials. The apparatus for the purpose will vary with the scale on which the experiment is to be made. If on a few ounces, glass retorts and flasks answer well, if good condensation is insured by means of a Liebig's condenser well supplied with very cold water. If a large quantity of prussic acid is to be made, such as several gallons, the apparatus should consist of a stoneware still, with head adjusted by grinding. The head should be capable of adjustment with a stoneware adapter to a worm of the same material enclosed in a tub of water. The joints are to be luted with a mixture of one handful of almond meal and five handfuls of linseed meal, worked with water to the consistence of putty. A solution of rough chloride of calcium in water is to be made and placed in a large iron pot, with a cover so contrived as to permit the still to drop in up to the flange. 10 parts of yellow prussiate of potash are then to be bruised in a mortar and mixed with dilute sulphuric acid prepared by adding 6 parts of sulphuric acid (density 1.850) to 42 of water. The head being luted on, a fire is to be kindled in the furnace under the iron pot, and the chloride of calcium both is to be kept boiling constantly until 36 parts of acid have distilled over. The blank of the still should be placed in the funnel which conducts the acid to the Winchester quart bottles which are to contain the product, and a piece of wet bladder is to be stretched over the funnel to prevent evaporation of the acid into the laboratory. The worm used for the purpose must be ascertained to be perfectly clean, and, if prussic acid is to be frequently made, should be kept specially for that operation. To each Winchester quart of the acid distilling over, one drop of sulphuric acid may be added to insure its keeping. But the acid thus prepared generally keeps for a long time even without this precaution, owing probably to small traces of the sulphuric acid being carried over during the distillation.

It is quite impossible to conduct the operation so as to yield a product of uniform strength; it is absolutely necessary, therefore, to determine the percentage of real hydrocyanic acid, and dilute it to the required degree. It fortunately happens that 1 grain of hydrocyanic acid yields almost exactly 5 grains of cyanide of silver; for one equivalent of acid = 27 produces 1 equivalent of cyanide of silver = 184; so that 27 : 184 : 1 : 4.98. The acid produced will have, probably, to be reduced to one of two standards; namely, the so-called Scheele's strength, containing 5 per cent. of acid, or the P.L., containing 2 per cent. : 100 grains of the former should, consequently, yield 25 grains, and 100 of the P.L. 10 grains of cyanide of silver. In either case the calculation becomes obvious.

Several processes for conducting this dangerous operation are known; the following is, perhaps, the most generally convenient. A large glass retort is so arranged that its neck is directed upwards at an angle of about 45°; a cork fitted to the
HYPOCHLOROUS ACID. 605

aperture in the neck connects a glass tube with a bottle containing a little chloride of calcium. From the latter vessel another tube proceeds to a U tube containing fragments of chloride of calcium, and from the latter a third, conducting the dehydrated vapor of prussic acid to an upright glass tube contained in a mixture of ice and salt. Into the retort is placed a mixture of 10 parts of yellow prussiate of potash, 7 of oil of vitriol, and 14 of water. The retort is to be heated with a charcoal flame, and the temperature of the bottle and U tube, containing the chloride of calcium, is not to be allowed to fall below 90°, in order to prevent condensation of the anhydrous prussic acid taking place anywhere except in the tube contained in the freezing mixture. The vapor of anhydrous prussic acid is so dangerous that the greatest precaution must be taken to prevent inhaling the smallest portion.

Detection of prussic acid.—When prussic acid exists in moderate quantity in a solution it may be detected by first adding a few drops of potash, then a mixture of protosulphate and persulphate of iron, and finally a little hydrochloric acid; a bright blue precipitate indicates the presence of the acid. A much more delicate test, and one that is applicable when, from the dilution of the solution, the salts of iron are no longer capable of acting, is by the conversion of the prussic acid into sulphocyanide of ammonium. For this purpose the prussic acid is to be warmed on a watch-glass with a drop of sulphide of ammonia, until the solution has become colorless. The addition of a trace of a solution of a persulphate of iron will show, by the formation of a blood-red color, the presence of the acid sought. A very neat mode of applying this test is to place one drop of sulphide of ammonia on a watch-glass inverted over another containing the suspected fluid. On leaving the apparatus in its place, arranged in this manner, for a short time, the upper glass will be found to contain sulphocyanide of ammonium, which, after drying, will be in a state well adapted for showing the reaction with a persulphate of iron.—C. G. W.

HYDRODYNAMICS. The mechanical science which treats of the motion of fluids. This science has, of course, most important bearings on the pumping-engines, water-wheels, &c., employed to facilitate the operation of the miner. It is not, however, possible to embrace this, which belongs to mechanical engineering, in this work.

HYDRO-EXTRACTOR. A name sometimes given to the machine employed for expelling the water from woven goods.

HYDROFLUORIC ACID. It was observed by Sewankhardt, in 1670, that fluor spar and oil of vitriol would eat into glass. Scheele, in 1771, determined that this peculiar property was due to the liberation of an acid from the fluor spar.

Hydrofluoric acid is best obtained by placing finely powdered fluor spar in a leaden retort, and twice its weight of highly concentrated oil of vitriol. By a gentle heat the gas is distilled over, which must be collected in a leaden tube, in which, by means of a freezing mixture, it may be condensed into a liquid. If a solution of this acid in water is required, the extremity of the tube from the retort is carried into a vessel of water.

Hydrofluoric acid attacks glass with great readiness, by acting on its silica.

Glass upon which any design is to be etched, is covered with an etching wax, and the design made in the usual manner; this is placed over a leaden vessel, in which is a mixture of fluor spar and oil of vitriol; a gentle heat being applied, hydrofluoric acid escapes, and immediately attacks the glass.

HYDROPHANE. A variety of opal which readily imbibles water, and when immersed it becomes transparent, though opaque when dry. It is found in Hungary, and in Ireland, near the Giant's Causeway, and at Croseleigh, Ballywillin.

HYDROSTATICS. The science which treats of the equilibrium of fluids, and of the pressure exerted by them.

In the engineering arrangements by which water is supplied to towns, hydrostatics becomes of the utmost importance. The highest possible level is obtained for the reservoir; and from this a series of pipes is arranged through all the streets and houses. The tendency of the water is to rise to its original level, and hence all the pipes are filled with water, and in all such as are below the level of the water in the reservoir a pressure upwards is exerted equal to the height of the reservoir above that point; and if a hole is pierced in the pipe, the water jets out with a force equal to this pressure. In the highest houses, the water perhaps only finds its level, and flows out without pressure quickly. See Water Pressure Machinery for Mines; Hydraulic Cranes.

HYPOCHLORIC ACID. CIO. Eq. 67-3. When finely powdered chloride of potash is gradually mixed into a paste with strong sulphuric acid, and heated in a bath of alcohol and water, a yellow gas is discharged which is this hypochloric acid, or the peroxide of chlorine. Although of much interest as a chemical compound, it has no use in the arts. See Ur's Chemical Dictionary.

HYPOCHLOROUS ACID. CIO. Eq. 49-3. This acid is best obtained by diffusing red oxide of mercury finely divided through twelve times its weight of water, which is introduced into a bottle containing chlorine, and agitated until the gas is absorbed. An oxychloride of
HYPOSULPHITES.

mercury is formed, which is removed by subsidence. The weak fluid obtained is put into a flask, and heated in a water bath, when the evolved gas is collected in a smaller portion of water, which becomes a pure solution of hypochlorous acid.

HYPOSULPHITES. Saline compounds formed by the union of hyposulphurous acid with bases.

Hyposulphate of Soda.—The salts of the hyposulphurous acid are obtained from the hyposulphate of manganese, which is itself thus prepared: finely divided binoxide of manganese is suspended in water, artificially cooled, and a stream of sulphurous acid passed through it. The binoxide gives up half its oxygen, becoming protoxide, which unites with the hyposulphuric acid which is formed, producing the soluble hyposulphate of manganese, which is separated from the excess of binoxide by filtration.

The following equation represents the reaction:—

\[ \text{MnO}_2 + 2\text{SO}_2 = \text{MnO}_3\text{SO}_4. \]

If the temperature were allowed to rise, sulphuric acid would be formed, and not hyposulphuric:

\[ \text{MnO}_3 + \text{SO}_2 = \text{MnO}_3\text{SO}_4. \]

The hyposulphuric acid, unlike the hyposulphurous acid, may be obtained in the free state, and its solution permits even of being evaporated \textit{in vacuo}, until it acquires the density of 1.247; but if carried further, it is decomposed into sulphuric and sulphurous acids.

The acid is obtained in the free state by adding baryta water to the hyposulphate of manganese; the soluble hyposulphate of baryta, filtered from the oxide of manganese, and precipitated exactly by the cautious addition of sulphuric acid, and filtered from the precipitate of sulphate of baryta, yields the pure solution of the acid, which may be evaporated \textit{in vacuo}, as above stated.

It has no odor, but a very sour taste.

The hyposulphate of soda may be made directly from the manganese salt or from the free acid. All the hyposulphates are soluble; they have not as yet met with any commercial application.

Hyposulphite of Soda.—This salt, now so extensively used for photographic purposes, was first introduced by Sir J. Herschel. It may easily be prepared by the following process, viz., by transmitting through a solution of sulphide of sodium (prepared by fusing together in a covered crucible equal weights of carbonate of soda and flowers of sulphur) a stream of sulphurous acid until it ceases to be absorbed; the liquid is then filtered and evaporated, when the hyposulphite of soda \((\text{NaO}_3\text{SO}_2 + 3\text{MIO})\) crystallizes out.

Another and perhaps better process consists in digesting a solution of sulphide of soda on flowers of sulphur. The sulphur gradually dissolves, forming a colorless solution, which yields on evaporation crystals of hyposulphite of soda; the reaction being shown by the following equation:—

\[ \text{NaO}_3\text{SO}_2 + 8 = \text{NaO}_3\text{SO}_3. \]

The baryta salt may be obtained in small brilliant crystals, by mixing dilute solutions of chloride of baryta and hyposulphite of soda.

The hyposulphurous acid is incapable of existing in the free state, for almost immediately on the addition of an acid to the solution of its salts, it is decomposed into sulphurous acid, with liberation of sulphur. \((\text{SO}_2^2 = \text{SO}_3 + 8.\)]

The soluble hyposulphites have the power, in a marked degree, of dissolving certain salts of silver, as the chloride, iodide, &c., which are insoluble in water; forming with them soluble salts, whose solutions possess an intensely sweet taste, although the solutions of the hyposulphites alone possess a disagreeable bitter taste.

From the above reaction arises the principal value of the hyposulphite of soda, which is used by the photographer to dissolve off from the photograph, after the action of the light on it, all the undecomposed silver salt, thus preventing the further action of the light on the picture.

A double hyposulphite of soda and gold is used for gilding the daguerreotype plate, and for coloring the positive proof obtained in photographic printing. This double salt may be obtained in a state of purity, by mixing concentrated solutions of 1 part of chloride of gold, and 3 parts of hyposulphite of soda; by the addition of alcohol it is precipitated; the precipitate must be redissolved in a small quantity of water, and again precipitated by alcohol. Its formation is explained by the following equation:—

\[ 8(\text{NaO}_3\text{SO}_3) + \text{AuCl}_3 = 2(\text{NaO}_3\text{SO}_2) + \text{AuO}_3\text{SO}_2, 3(\text{NaO}_3\text{SO}_3) + 2\text{NaCl}. \]


H. K. B.
ILLUMINATION. The numerical estimation of the degrees of intensity of light constitutes that branch of optics which is termed Photometry.

Bunsen's photometer consists of a sheet of cream-colored letter paper, rendered transparent over a portion of the surface by a mixture of spermaceti and rectified naphtha, which is solid at common temperatures, but becomes liquid on the application of a very gentle heat. The mixture is liquefied and painted over the paper with a brush, leaving a round disc of the size of half a crown in the centre uncovered. When a light is placed on one side of the paper a dark spot is observed on the uncovered portion. When another light is placed on the other side of the paper, the spot is still distinctly visible, if the distance of the light is such that the reflected portion from the paper be either of greater or of less intensity than that transmitted. When the paper is so situated between the two flames that the transmitted and reflected light are of the same intensity, the uncovered spot is no longer visible.

It is possible only, to compare one light with another; there is not any arrangement by which we are enabled to express absolutely the illuminating power. Upon the principle of comparison, and comparison only, the following tables have been constructed by the relative experimentalists. The following comparative view of wax and stearine candles manufactured in Berlin, which have been deduced from the observations of Schubart, is of much value.

<table>
<thead>
<tr>
<th>Kind of candles, and whence obtained</th>
<th>Relative intensity of light</th>
<th>Consumption in one hour, in grammes</th>
<th>Relative illuminating power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common wax candles, of Tannhäuser</td>
<td>8's: 103.5</td>
<td>9.757</td>
<td>85.20</td>
</tr>
<tr>
<td></td>
<td>6's: 91.0</td>
<td>7.757</td>
<td>83.20</td>
</tr>
<tr>
<td></td>
<td>100.0</td>
<td>6.562</td>
<td>100.0</td>
</tr>
<tr>
<td>Wax candles, of Walker</td>
<td>4's: 122.7</td>
<td>9.398</td>
<td>92.66</td>
</tr>
<tr>
<td></td>
<td>6's: 120.3</td>
<td>8.082</td>
<td>97.69</td>
</tr>
<tr>
<td></td>
<td>5's: 113.1</td>
<td>7.132</td>
<td>104.1</td>
</tr>
<tr>
<td>Stearine candles, of Motard</td>
<td>4's: 117.4</td>
<td>9.427</td>
<td>81.74</td>
</tr>
<tr>
<td></td>
<td>6's: 111.8</td>
<td>8.353</td>
<td>78.23</td>
</tr>
<tr>
<td></td>
<td>5's: 121.9</td>
<td>7.877</td>
<td>100.9</td>
</tr>
<tr>
<td>Stearine candles, of Magnet and Oelmichen</td>
<td>4's: 139.5</td>
<td>10.62</td>
<td>86.11</td>
</tr>
<tr>
<td></td>
<td>6's: 132.7</td>
<td>9.398</td>
<td>92.66</td>
</tr>
<tr>
<td></td>
<td>8's: 125.0</td>
<td>8.505</td>
<td>96.54</td>
</tr>
<tr>
<td>Stearine candles, from the same makers</td>
<td>6's: 116.1</td>
<td>8.871</td>
<td>85.86</td>
</tr>
<tr>
<td></td>
<td>4's: 143.0</td>
<td>8.858</td>
<td>108.9</td>
</tr>
<tr>
<td></td>
<td>8's: 134.5</td>
<td>9.890</td>
<td>82.27</td>
</tr>
<tr>
<td>Candles made from palm oil</td>
<td>6's: 115.3</td>
<td>9.178</td>
<td>82.56</td>
</tr>
<tr>
<td></td>
<td>8's: 167.5</td>
<td>8.813</td>
<td>113.70</td>
</tr>
</tbody>
</table>

These results show us that the mean illuminating power of wax and stearine candles is nearly the same.

INDIGO. We are indebted to Dr. Roxburgh, for a description of the method employed for manufacturing indigo from the Nerium indicum or Wrightia indicaria. (Vide Transactions of the Society of Arts, vol. xxviii.) This plant, which attains the size of a small tree, is found on the lower regions of the mountainous tract near Ramanjunday, and also on hills in the neighborhood of Salem and Pondicherry, and grows in a sterile as well as rich soil. The leaves begin to appear in March and April, and at the end of April have attained their full size, when they are ready for gathering. At the end of August they begin to assume a yellowish rusty color, and soon fall off. The leaves yield no indigo until the plant is several years old, but the best leaves for making indigo are obtained from low bushy plants. They improve when kept for a day or two, but when they begin to wither, they yield but a small portion of very bad indigo, and when quite dry only a dirty brown fecaule. In this they differ from leaves of the common indigo plant, which may be dried before extraction without loss of color. They also differ from the latter in not yielding their color to cold water. With cold water only a hard, black, flinty substance is obtained, not blue indigo. It is therefore necessary to employ hot water, which extracts the color very readily. The leaves, having been collected, are on the ensuing day thrown into copper scalding-vessels, which are then filled with cold water to within 2 or 3 inches of the top. Hard water containing a large quantity of bicarbonate of lime is better adapted for the purpose than rain water. The fire is then lighted and maintained rather briskly until the liquor acquires a deep green color. The leaves then begin to assume a yellowish color, the heat of the liquor being about 150° to 160°.
Fahr. The fire is then removed and the liquor run off into the beating-vat. Here it is agitated from 5 to 20 minutes. It is then mixed with about \( \frac{7}{10} \text{ to } \frac{7}{186} \) part of fine water, which produces a speedy granulation. After the indigo has subsided the supernatant liquid appears of a clear Madeira wine color. The quantity of indigo obtained amounts to 1 lb. from 250 lbs. of green leaves; but it varies according to the season and the state of the weather. In August and September, the produce is only one-half or two-thirds of what it is in May and June, and even that is diminished if the weather is wet, or the leaves are treated immediately after being gathered. The scalding requires about three hours, and the agitation and precipitation the same time. The indigo is improved by treating it with a little sulphuric acid. The only fault it has is, that it breaks into small pieces, unless it has been dried slowly in the shade, protected from the sun.

In the southern provinces of China a species of Indigofera is extensively cultivated for the sake of the dye which it affords. In the northern provinces two other plants are employed by the inhabitants for the same purpose. Mr. Fortune, the well-known Chinese traveller, to whom we owe the description of these plants and of the process of manufacturing indigo from them, states that one of them is grown in the neighborhood of Shanghae, and he has given it the name of Isatis indigotica. The other, which is a species of Justicia, is largely cultivated in the hilly country near Ningpo, or rather in the valleys among the hills. It seems to be easily cultivated; it grows most luxuriantly, and is not doubt very productive. Having evidently been introduced from a more southern latitude, it is not hardy in the province of Chekiang any more than cotton is about Shanghae; but nevertheless it succeeds admirably as a summer crop. It is planted at the end of April or beginning of May, after the spring frosts are over, and it is cleared from the ground in October. During this period it attains a height of a foot or a foot and a half, becomes very bushy, and is densely covered with large green leaves. It is cut before any flowers are formed. The plants are grown, not from seed but from cuttings. These cuttings consist simply of a portion of the stems of the previous year, which, after being stripped of their leaves, are tied into bundles, each containing upwards of 1,000, and kept during the winter in a dry shed or out-house, where, after being firmly packed together, they are banked round with dry loam, and covered with straw or litter so as to protect them from the frost. During the winter months the cuttings remain green and plump, and although no leaves are produced a few roots are generally found to be formed or in the act of forming when the winter has passed and the season for planting has come round. In this state they are taken to the fields and planted. The weather during the planting season is generallyshowery, as this happens about the change of the monsoon, when the air is charged with moisture. A few days of this warm showery weather is sufficient to establish the new crop, which now goes on growing with luxuriance and requires little attention during the summer, indeed none except keeping the land free from weeds. In the country where this dye is manufactured there are numerous pits or tanks on the edge of the fields. They are usually circular in form, and have a diameter of about 11 feet and a depth of 3 feet. About 400 catties* of stems and leaves are thrown into a tank of this size, which is then filled to the brim with clear water. In five days the plant is partially decomposed, and the water has become yellowish-green in color. At this period the whole of the stems and leaves are removed from the tank with a flat-headed broom made of bamboo twigs. When every particle has been removed, the workmen employed give the water a circular and rapid motion with the brooms just noticed, which is continued for some time. During this part of the operation another man has employed himself in mixing about thirty catties of lime with water, which water has been taken out of the tank for the purpose. This is now thrown into the tank, and the rapid circular motion of the water is kept up for a few minutes longer. When the lime and water have been well mixed in this way the circular motion is allowed to cease. Four men now station themselves round the tank and commence beating the water with bamboo rakes made for this purpose. The beating process is a very gentle one. As it goes on, the water gradually changes from a greenish hue to a dingy yellow, while the froth becomes of a beautiful bright blue. During the process the head workman takes a pailful of the liquid out of the tank and tastes it rapidly with his hand. Under this operation it changes color at once, and its value is judged of by the hue it presents. The beating process generally lasts for about half an hour. At the end of this time the whole of the surface of the liquid is covered with a thick coating of froth of the most brilliant colors, in which blue predominates, especially near the edges. At this stage, it being desirable to incorporate the froth with the liquid below it, it is only necessary to throw a small quantity of cabbage oil on the surface of the froth. The workmen then stir and beat it gently with their flat brooms for a second or two, and the whole instantly disappears. The liquid, which is now darker in color, is allowed to repose for some hours, until the color of the froth which has sunk to the lower stratum, when about two-thirds of the liquid is drawn off and thrown away. The remaining third part is then drawn into a small square tank on a lower level,

* A Chinese catty is equal to 1 lb.
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which is thatched over with straw, and here it remains for three or four days. By this time the coloring matter has separated itself from the water, which is now entirely drained off, the dye occupying three or four inches of the bottom in the form of a thick paste and of a beautiful blue color. In this state it is packed in baskets and exposed for sale in all the country towns in this part of China. Like the Shanghai Indigo, made from Indigofera straps, it is called "Zie-cheing" by the Chinese.—Gardner’s Chronicle and Agricultural Gazette, April 8th, 1854.

The cultivation of indigo in Central America has fallen of very much of late years. Nicaragua formerly exported annually about 5,000 bales of 150 lbs. each. At present the export probably does not exceed 1,000 or 2,000 bales. Under the government of Spain, the state of San Salvador produced from 8,000 to 10,000 bales annually. A piece of ground equal to two acres generally produces from 100 to 120 lbs., at a cost of not far from 30 to 40 dollars.

There is an indigenous biennial plant abounding in many parts of Central America, which produces indigo of a very superior quality, but gives less than half the weight which is afforded by the cultivated species. The Indigofera dysperosa is the species employed in cultivation. It attains its highest perfection in the richest soils. It will grow, however, on land, and is very little affected by drought or by superabundant rains. In planting it, the ground is perfectly cleared, usually burnt over, and divided with an implement resembling a hoe into little trenches, 2 or 3 inches in depth, and 12 or 14 apart, at the bottom of which the seeds are strewn by hand, and lightly covered with earth. A bale of seed answers for 4 or 5 acres of land. In Nicaragua it is usually planted in the close of the dry season in April or May, and attains its perfection for the purpose of manufacture in from two and a half to three months. During this time it requires to be carefully weeded, to prevent any mixture of herbs, which would injure the quality of the indigo. When it becomes covered with a kind of greenish farina, it is in a fit state to be cut. This is done with knives at a little distance above the root, so as to leave some of the branches, called in the West Indies “ratoons,” for a second growth, which is also in readiness to be cut in from six to eight weeks after. The crop of the first year is usually small; that of the second is esteemed the best, although that of the third is hardly inferior. It is said that some fields have been gathered for ten consecutive years without being re-sown, the fallen seed obviating the necessity of new plantings.

After the plant is cut, it is bound in little bundles, carried to the vats, and placed in layers in the upper or larger one called the steepers, (majadors.) This vat holds from 1,000 to 10,000 gallons, according to the requirements of the estate. Boards loaded with weights are then placed upon the plants, and enough water let on to cover the whole, which is now left to steep or ferment. The rapidity of this process depends much upon the state of the weather and the condition of the plant. Sometimes it is accomplished in 8 or 9 hours, but generally requires from 15 to 20. The proper length of time is determined by the color of the saturated water; but the great secret is to check the fermentation at the proper point, for upon this, in a great degree, depends the quality of the product. Without disturbing the plant, the water is now drawn off by cocks into the lower vat or "beaters," (golpeadores,) where it is strongly and incessantly beaten, in the smaller estates with paddles by hand, in the larger by wheels turned by horse or water power. This is continued until it changes from the green color, which it at first displays, to a blue, and until the coloring matter, or floccule, shows a disposition to curl or subside. This is sometimes hastened by the infusion of certain herbs. It is then allowed to settle, and the water is carefully drawn off. The pulp granulates, at which time it resembles a fine soft clay; after which it is put into bags to drain, and then spread on cloths in the sun to dry. When properly dried, it is carefully selected according to its quality, and packed in bale cases, 150 lbs. each, called serona. The quality has not less than 9 gradations, the best being of the highest figure. From 6 to 9 are called flores, and are the best; from 3 to 6 cortes: from 1 to 3, inclusive, cobres. The two poorer qualities do not pay expenses. A manana of 100 yards square produces on an average about one serona at each cutting. After the plant has passed through the vats, it is required by law that it shall be dried and burnt; because in decomposing it generates by the million an annoying insect called the "indigo fly."*

* The following account of the manufacture of indigo on the Senegal is taken from Perrotet’s "Art de l’Indigoier.

The land destined to the cultivation of the plant ought to be perfectly level and free from undulations, so as to prevent the seed from being washed into the hollows or lower parts by the heavy rains so frequent in the tropics. Soils of a grayish color abounding in clay are not adapted for the purpose, as they are too compact and cold. Sandy soils of a whitish color must also be avoided. Light soils, abounding in humus or vegetable remains, and having a color between gray and dark brown, are to be preferred to all others. The soil should, at all events, not be one very retentive of moisture. The
quantity of indigo obtained from the same weight of plant may vary, according to the soil, from 4 lbs. to 10 lbs., and the quality also varies in a corresponding degree. The extent of ground which is required for the production of indigo on a large scale is so great that the use of manure becomes almost impossible. Nevertheless the employment of the refuse of the plant, after the extraction of the indigo, as a manure on fresh plantations, is found to be attended with very beneficial results. The ground, if new, must be turned up by means of a plough or hoe, to the depth of at least 10 or 12 inches, three times successively at intervals of 3 weeks, before the sowing takes place. The sowing must only be undertaken in fine weather, never during heavy rain. The seed employed should be perfectly ripe, and, if possible, not more than one year old. It is to be left in the seed-vessels in which it is contained until the time when it is wanted. The latter are then put into a wooden mortar and reduced to fragments, and the seed is separated by winnowing from the dust, débris, &c., with which it is mixed. The sowing is to be effected broadcast and as evenly as possible. It should take place, if possible, just before the approach of rain, in which case the use of a harrow is not required, as the rain generally has the effect of completely levelling the ground and covering up the seed with soil. The Indigofera tinctoria, and its varieties macrocarpa and emarginata, being a plant with numerous crowded branches, it is not necessary, in sowing it, to take more than from 6 to 7½ kliogr. of seed to 1 arpent of ground; but the Indigofera unil, being more sparingly branched, and therefore taking up less room, requires to be more thickly sown. At about ten or twelve days after sowing, when the young indigofera have attained a height of about 81 to 108 millimètres, the ground must be carefully weeded, and this operation must be repeated as soon as the weeds have again made their appearance and commenced to interfere with the growth of the crop. When the season is favorable, three months are generally sufficient to enable the plants to attain the degree of development necessary for the production of indigo. At the period when indigofera commences the plant is far richer in coloring matter than at any other. As soon, therefore, as there are any indications of flowering, and when the lower leaves, in the axis of which the flowers appear, begin to acquire a yellowish tint, and when pressed in the hands produce a small crackling noise, no time must be lost in cutting down the plant. This is effected by means of good knives or sickles, and as near the ground as possible. The stems, after being cut, are tied together into bundles, leaves and carried to the manufactory. Since the coloring principle of the indigofera is extremely susceptible of change by the action of destructive agencies, it is necessary to use the utmost despatch in gathering the crop, and to have the manufactory of such a size in proportion to the plantation, that no time may be lost in working up the material as soon as gathered. The plants must on no account be cut when they are moistened either with rain or dew, because in this case they acquire a blackish tint in consequence of the friction to which they are exposed in cutting them and taking them to the manufactory, this tint being a sign of the disappearance of the coloring matter. Besides this, it has been observed that during the continuance of rain the indigo-producing principle diminishes very considerably, and sometimes even disappears entirely, so that, if cut during or immediately after rain, the plants yield little or no indigo. The indigo plant is subject to the attack of a green caterpillar, which sometimes appears in such quantities as to destroy the whole crop. No certain and easy means of destroying this pest is known. It has been recommended to pass wooden rollers over the ground, before the plants have attained any great size, so as to crush the caterpillars without injuring the plants, and this plan has been attended with partial success.

In order to obtain good results in the manufacture of indigo, it is necessary that the plants should be of the same age, of the same species, and from the same field. The Indigofera unil begins to ferment several hours sooner than the I. tinctoria, so that if a mixture of both be taken, the produce from either one or the other will be lost, and the indigo obtained will also be of a bad quality. The plants should, as soon as possible after being gathered, be placed in the steeping-vat, which is a vessel built of bricks, and well lined with cement, from 3½ to 8 metres in length, of the same width, and about 1 metre deep. In this vessel the plants are arranged in successive layers, the lower layers being slightly inclined towards one end, in order to facilitate the subsequent running off of the liquor. The vessel being full, a number of poles of fir-wood are laid lengthways over the plants, at a distance of 182 mill. from one another. Three beams are then laid crosswise over the poles, their ends being well secured by passing them through slots which are cut in the upright posts at the sides of the cistern, and then fixing them by means of iron pins, passing through holes in the posts. By this means the plants are prevented from rising above the surface of the liquor during the process of maceration. The vat is now filled with water from an adjacent cistern, in which it has been allowed to stand for 24 hours for the sole purpose of allowing all foreign matter to be deposited. After standing in contact with the leaves for about 6 hours, a change usually begins to manifest itself in the liquor, which must therefore, from that time for-
ward, be carefully watched. As soon as this liquor begins to acquire a green color, and with like effect on the lips, for a short time in the mouth, leaves a slight impression of harshness (apercé) on the tongue and the palate, it is a sign that the maceration is complete, and that the liquor should be drawn off without delay. If this be not done, the color of the liquor changes from green to brown, a new species of fermentation commences, accompanied by the formation of acetic acid, and the plant begins to yield substances of a mucilaginous nature, which contaminate the indigo, and completely spoil its quality. It is therefore of the greatest importance to ascertain exactly when the maceration of the plant is complete. The following are the chief indications of this point having been attained: 1. When the water, which was at first clear, begins to become muddy and acquire a slight greenish tinge. 2. When bubbles of a greenish color rise to the surface here and there. 3. When towards the edge of the vat some mucilage, or a kind of grayish scum, commences to be formed. 4. When a very slight purple pellicle is observed on the surface of the liquor, especially near the corners of the vat. 5. When the liquor begins to exhale a slight but not disagreeable odor of herbs. When the fermentation has proceeded too far, the following phenomena present themselves: 1. A considerable quantity of large bubbles of air are disengaged, which burst at the surface, forming a layer of grayish mucilage. 2. The surface of the liquor becomes covered with a mucilaginous pellicle. 3. A heaving of the liquor in the vat is observed, giving rise to the disengagement of large greenish bubbles which communicate a brownish color to the water. 4. The liquor acquires a fetid smell, a strongly acid taste, and a soapy appearance. These phenomena manifest themselves when the weather is hot, after the fermentation has continued about 12 or 14 hours. It then becomes impossible to obtain indigo of good quality, the only product being a black matter resembling pitch. The liquor is now run off from the steeping-vat into the beater, which is a cistern of about the same dimensions as the former, but situated at a rather lower level. Here it is subjected to the beating process, the object of which is to expose the reduced indigo to the oxygen of the atmosphere, as well as to promote the disengagement of the carbonic acid gas with which the liquid is charged, and which prevents the precipitation of the indigo. The beating is performed by men, who, provided with paddles, agitate the liquid rapidly, so as to bring every part of it successively into contact with the air. It is of importance that this process should be broken off at the right moment, for if it be continued too long, the grain formed at first will redissolve and be lost. And if, on the other hand, it be arrested before the proper time has arrived, a portion of the indigo will remain unprecipitated. In order to ascertain in what state the liquor is, a little of it must be poured into a drinking-glass and mixed with an equal volume of clear water. If there is formed round the circumference of the glass a line of a bluish-green color, the beating must be continued; but if, on the contrary, the liquid appears of a uniform brown color, and if on adding to it a few drops of clear lime water with the finger the indigo precipitates immediately in grains, the process must be arrested. The beating usually occupies from an hour and a half to two hours. The liquid is now to be well mixed with about 1/10 of its volume of clear lime water, and allowed to rest until the indigo has quite settled. By opening successively the plugs which are placed at different heights in the side of the vessel, the clear liquor is then drawn off in separate portions and permitted to run away, care being taken that none of the indigo is allowed to be carried away with the water. By means of an opening situated at the bottom of the beating vat the indigo mixed with water is then run off, and, flowing through a canal, is received on a cloth strainer or filter. This filter rests on a round or four-cornered vessel, the top of which is on a level with the surface of the ground, and which is called the diablotin. When the liquor has run through the filter, the indigo which remains behind in a state of paste is mixed up again with water, and the mixture is poured on a canvas filter and allowed to run immediately into the boiler. The refuse matter, consisting of leaves of the plant, &c., remains on the canvas, while the indigo suspended in water runs through. The boiler is a vessel with sides of masonry and a bottom consisting of a copper plate which rests on iron bars, and is well cemented to the sides. Underneath the copper plate is the fire-place. The top must be covered with a wooden lid, consisting of two haps which are fixed to hinges at the sides, and meet together over the top. At the moment when the mixture of indigo and water is introduced into the boiler, the latter must already be about one-third full of hot water, the mixture being sufficient almost to fill it entirely. The heat is now raised gradually to the boiling point, and the boiling is continued for about two hours. In order to prevent the indigo from adhering to the bottom and sides of the boiler, the liquor must be kept continually stirred with a wooden rake. The object of the boiling is to drive away all the carbonic acid that may still be present in the liquor, to remove the soluble extractive matters which would render the indigo dull and impure, to prevent the fermentation or putrefaction of the indigo which would otherwise take place, and, lastly, to facilitate the subsequent processes of filtering and pressing. The fire having been removed, the liquor is allowed to stand for some time, and as soon
as the indigo has settled the supernatant liquid is drawn off by means of taps fixed in one of the sides of the boiler. The lowest tap is then opened, and the indigo is run off with the water and received on a filter, consisting of blue Guinea cloth stretched on a frame. The first portion of liquid which run through are usually colored with indigo, and must therefore be caught in a suitable vessel and poured on the filter again. As soon as the liquid has percolated, the indigo, which is now a compact paste, is removed from the filter by means of a wooden ladle and put into a press, which consists of a wooden box pierced with holes. The press having been lined with cloth, the indigo is put in, the cloth is folded round it as evenly as possible, a wooden lid is dropped on the cloth, and the mass is subjected to pressure by means of a screw, until no more liquid runs through at the bottom, which takes place as soon as the indigo has been reduced to about a third of its original volume. The press is then opened, the indigo is taken out of the cloth, laid on a table, and divided by means of a knife into pieces of a cubical shape. These cubes are then taken to the drying-shed, where they are placed on trellises covered with matting or very thin cloth, so as to admit of the free passage of air. Care must be taken not to dry them too rapidly, otherwise the cakes would crack and split into fragments, which are then of little commercial value, and it is therefore necessary to protect them from currents of dry air by covering them with canvas or Guinea cloth. During the drying process, which occupies from 8 to 10 days, the cakes should be turned several times. They are then closely packed in boxes, each box holding about 20 kilograms. The boxes should be lined with paper.

It may be remarked, that when the indigo is of good quality, the volume of the paste diminishes very little when subjected to pressure. If the process of filtering takes up much time and the pressing is attended with difficulty, it may be anticipated that the indigo will turn out of bad quality. This may proceed from the plant having been overgrown, or from the maceration or the beating process having been continued too long, or from the employment of too large a quantity of line water. The difficulty experienced in pressing the indigo paste, and which is often so great as to cause the cloth in which it is enveloped to break, is caused by the presence of a mucilaginous or viscous substance mixed with the indigo, which may be removed by treating the paste again with boiling water, and repeating the operations of filtering and pressing.

In regard to the state in which indigo exists in the plants from which it is derived, and the nature of the process by which it is obtained, various opinions have been entertained by chemists. Berthollet, in his work on dyeing, says, "that the three parts of the process employed have each a different object. In the first a fermentation is excited, in which the action of the atmospheric air does not intervene, since an inflammable gas is evolved. There probably results from it some change in the composition of the coloring particles themselves; but especially the separation or destruction of a yellowish substance, which gave to the indigo a greenish tint, and rendered it susceptible of undergoing the chemical action of other substances. This species of fermentation passes into a destructive putrefaction, because the indigo has a composition analogous to that of animal substances. Hitherto the coloring particles have preserved their liquidity. In the second operation, the action of the air is brought into play, which, by combining with the coloring particles, deprives them of their solubility, and gives them the blue color. The heating serves, at the same time, to dissipate the carbonic acid which is formed in the first operation, and which by its action presents an obstacle to the combination of the oxygen. The separation of this acid is promoted by the addition of lime; but if an excess be introduced, it counteracts the free combination of the oxygen. The third part of the process has for its objects, the deposition of the coloring matter, become insoluble by combination with oxygen, its separation from foreign substances, and its desiccation, which gives it more or less hardness, whence its appearance varies." De Cossigny was of opinion that volatile alkali was the agent by which the coloring matter was extracted from the plant and held in solution until volatilized by the agitation process. Roxburgh concluded from his experiments, "that the indigo plants contain only the base of the color, which is naturally green; that much carbonic acid is dissipated during its extraction from the leaves; that the carbonic acid is the agent whereby it is probably extracted and kept dissolved; that ammonia is not formed during the process; that the use of the alkalis employed is to destroy the attraction between the base and the carbonic acid; and that the vegetable base, being thereby set at liberty, combines with some coloring principle from the atmosphere, forming therewith a colored insoluble fecula, which falls to the bottom and constitutes indigo." Chevrel, who was the first chemist of any eminence to examine the indigo-bearing plants and their constituents, inferred from his analyses of the Isatis tinctoria and the Indigofera annul, that these plants contain indigo in the white or reduced state, in the same state in which it exists in the indigo vat; that in this state it is held in solution by the vegetable juices, and that when the solution is removed from the plant it is converted by the action of the atmospheric oxygen into indigo-blue. Gledert, from an examination of the Isatis tinctoria, drew the following conclusions: 1. Indigo-blue does not preexist in the
plant, but is formed during the operations by means of which we believe it to be extracted.

2. There exists in a small number of plants a peculiar principle, different from all the known proximate constituents of plants, and which has the property of being convertible into indigo; this principle may be called indigogen. 3. This principle differs from indigo in containing an excess of carbon, of which it loses a portion, in passing into the state of indigo-blue, by the action of a small quantity of oxygen which it takes up. 4. The loss of this portion of carbon must be attributed to its undergoing combustion and being converted into carbonic acid. 5. It differs in its properties from common indigo in being colorless and soluble in water, and by its greater combustibility, which causes it to undergo spontaneous combustion at the ordinary temperature of the atmosphere. 6. Its combustibility is enhanced by heat and by combination with alcalies, especially lime; it is diminished by the action of all acids, even carbonic acid. About the year 1839, the Pygogonum tincturianum, an indigo-bearing plant indigenous to China, became the subject of a series of investigations by several French chemists, chiefly with a view to ascertain whether this plant, if grown in France, could be advantageously employed in the preparation of a dyeing material as a substitute for foreign indigo. Baudrimont and Pelletier, after an examination of this plant, arrived at the conclusion that the indigo is contained in it as reduced indigo, in the same state as it is in wood, according to Chevreul. Robiquet, Colin, Turpin, and Joly, on the other hand, expressed a very decided conviction that indigo-blue preexists in the plant, but not in a free state; that it is combined with some organic substance or substances which render it soluble in water, ether, and alcohol; and that the operation of potent agencies is requisite in order to destroy this combination and set the indigo at liberty. The explanation of Chevreul, proceeding from an authority of such eminence, and being the simplest, has been adopted by most chemists. Nevertheless there are objections to it which render it inadmissible. Reduced indigo is a body which is only soluble in alcalies, and cannot, therefore, be contained as such in the juice of indigo plants, which is mostly acid. As it also takes up oxygen with the greatest avidity, and is converted into indigo-blue, it is difficult to conceive how the whole of it can be preserved in a colorless state in the cells of plants, in which it must occasionally come in contact with the oxygen eliminated by the vegetable organism. If these plants contained reduced indigo, the juice ought, moreover, to turn blue the moment it became exposed to the atmosphere, which is not always the case.

The necessity for a long process of fermentation in order to obtain the coloring matter would also not be very apparent, the mere contact with oxygen being, it might be supposed, all that was necessary for the purpose. The facility with which the indigo-blue is destroyed if the process of fermentation is carried too far, is also inconsistent with the supposition that it is contained in plants, either as such or in a deoxidized state, since indigo-blue is a body not easily decomposed, except by very powerful agents.

In order to throw some light on this subject, an investigation was undertaken by Schunck into the state in which indigo-blue exists in the Isatis tinctoria, or common woad, which is the only plant indigenous to Europe that yields any considerable quantity of the coloring matter. Schunck succeeded in obtaining from that plant a substance of very peculiar properties, to which he gave the name of Indeem. This substance has the appearance of a yellow or light brown transparent syrup. It has a bitter taste. It is very easily soluble in water, alcohol, and ether; its solutions are yellow, and have an acid reaction. Its compounds with bases are yellow. When its watery solution is mixed with a strong acid, such as muriatic or sulphuric acid, no change takes place at first, but on leaving the solution to stand, or on heating it, it becomes blue and opalescent, then acquires a purple color, and finally deposits a quantity of purple-blue flocks, which are quite insoluble in water. These flocks consist for the most part of indigo-blue, but they contain also a red coloring matter and several brown substances of a resinous nature. The supernatant liquid contains a peculiar kind of sugar, and on being distilled yields carbonic, formic, and acetic acids. Hence it follows that the plant does not contain indigo-blue ready formed, either in the blue or colorless state—that the latter exists in the vegetable juice in a state of combination with sugar, forming a compound of that peculiar class known to chemists as glucosides. This compound is readily dissolved by water, and the indigo-blue may then be liberated and precipitated from the solution by means of acids, and probably also by other agents, but the simultaneous action of oxygen is not necessary during the process of decomposition which the plant undergoes in yielding indigo-blue. Now if, as seems probable, the various species of indigofera contain indine or some similar substance, the phenomena which take place during the process of manufacturing indigo may easily be explained. During the steeping process the indican is dissolved, and in consequence of the fermentation which then takes place in the liquor it is decomposed into indigo-blue and sugar. The former would then be precipitated, but since ammonia is, according to most authors, evolved at the same time, the indigo-blue is, by the simultaneous action of the alkaline matters contained in the liquor, reduced and dissolved, forming a true indigo vat, from which the coloring matter is afterwards precipitated by the combined action of the atmospheric oxygen and the lime, during the beating pro-
cess. According to Schunck, two distinct periods may be observed in the decomposition of indigo. During the first period, indigo-blue is the chief product of decomposition; during the second, the red and brown resinous matters make their appearance with very little indigo-blue. The formation of carbonic, acetic, and formic acids is, according to Schunck, dependent on that of the brown resinous matters. It would appear, therefore, that the copious disengagement of carbonic acid, as well as the acid taste, attributed to acetic acid, sometimes observed during the manufacture of indigo, are phenomena which indicate the formation, not of indigo-blue, but of other substances, which may prove very injurious to the quality of the indigo. These substances, being soluble in alkalies, but insoluble in water, are precipitated, as soon as the liquid loses the alkaline reaction which it possesses at the commencement, and becomes acid. Though indigo-blue is a body of very stable character, not easily decomposed when once formed, except by potent agencies, still the assertion of Perottet and others, that "nothing is more fugitive and more liable to be acted on by destructive agencies than the coloring principle of the indigofera," will be easily understood when the following facts, mentioned by Schunck, are taken into consideration: If a watery solution of indigo, this indigo-producing body, be boiled for some time, it then yields by decomposition, not a trace of indigo-blue, but only indigo-red, and if it be boiled with the addition of alkalis, it then gives neither indigo-blue nor indigo-red, but only the brown resinous matters before mentioned. The mere action of alkalis is therefore sufficient to cause the molecules, which would otherwise have gone to form indigo-blue, to arrange themselves in a totally different manner and yield products which bear very little resemblance to it. It is evident, therefore, that one of the chief objects to be kept in view by the manufacturer of indigo, is the proper regulation of the process of fermentation, so as to prevent the formation of the other products, which take the place of indigo-blue, and are formed at its expense.

The indigo of commerce occurs in pieces, which are sometimes cubical, sometimes of an irregular form. These pieces are firm and dry, and are easily broken, the fracture being dull and earthy. It is sometimes lighter, sometimes apparently heavier than water, this difference depending on its being more or less free from foreign impurities, as well as upon the treatment of its paste in boiling, pressing, and drying operations. Its color is blue of different shades, as light blue, purplish blue, coppery blue, and blackish blue. On being rubbed with the nail, or a smooth hard body, it assumes the lustre and blue of copper. It is usually a homogeneous mass, but it occasionally contains grains of sand or other foreign bodies, and sometimes presents inequalities of color. It is frequently full of small cavities, which proceeds from the drying process having been conducted too rapidly, and it is also covered at times with a whitish matter consisting of mould. It varies very much in consistency, being sometimes dry, hard, and compact, whilst sometimes it is easily broken into thin flat pieces. Indigo is devoid of smell and taste. When applied to the tongue, however, it adheres slightly. In consequence of the property which it possesses of rapidly absorbing moisture—a property which is often had recourse to in order to ascertain its quality. When thrown on red-hot coals it yields vapors of a deep purple color, which, when condensed on cold bodies, give shining needles having a coppery lustre. It is insoluble in water, cold alcohol, ether, muriatic acid, dilute sulphuric acid, cold ethereal and fat oils; but boiling alcohol and oils dissolve a little of it, which they deposit on cooling. Creosote has the property of dissolving indigo.

Indigo varies very much in quality, but it requires much discrimination in order to judge fairly of the quality of any sample from mere inspection and application of the tests usually employed by dealers. A cake of indigo being broken, and the nail or the edge of a shilling being passed with a tolerable degree of pressure over the fractured part, a fine coppery streak will be produced if the indigo is good. If the indigo furrows up on each side of the nail it is weak and bad, and if the coppery streak be not very bright it is not considered good. When a piece of indigo is broken the fracture should be held up to the sun, and if it has not been well strained from the dross, particles of sand will be seen glittering in the sun-light. The outside or coat should also be as free from sand as possible. When the squares are broken in the chests the indigo fetches a low price, and if it is very much crushed it is only bought by the consumers for immediate use. The methods employed for ascertaining the true amount of coloring matter in any sample of indigo will be described below.

Indigo is generally classified according to the various countries from which it is obtained. The principal kinds are the following: Bengal, Oude, Madras, Manilla, Java, Egyptian, Guatemalan, Caracas, and Mexican. At the present day the finest qualities of indigo are obtained from Bengal, the produce of that country having now taken the place in public estimation which was once occupied by that of the Spanish colonies. The export of indigo from Bengal, which in 1853 amounted to 120,000 maunds, (of 74 lbs. 10 oz.,) would require for its culture about 1,025,000 acres, and an annual expenditure of £1,900,000. Of this extent of land about 550,000 acres are believed to be included in the Lower Provinces, and consist chiefly of
alluvial land rescued from the rivers. The best qualities of Bengal indigo are manufactured in the Jessore and Kishenaghat districts, but each district produces a quality peculiar to itself, and differences of a less striking character may be perceived in the produce of different factories. The Bengal indigo, when packed in chests, consists of four principal qualities, viz., the blue, purple, violet, and copper. But these kinds, by passing over into one another, produce a number of intermediate varieties, such as purplish blue, blue and violet, purplish violet, &c. The various qualities would, therefore, be distinguished as follows: 1. Blue. 2. Blue and violet. 3. Purple. 4. Purple and violet. 5. Violet. 6. Violet and copper. 7. Copper. The leading London brokers, however, classify Bengal indigo into the following grades: fine blue, fine purple and violet, fine red and violet, good purple and violet, middling violet, middling defective, consuming fine, middling and good, ordinary, ordinary and lean trash. The finest qualities of Bengal indigo present the following characteristics: They consist of cubical pieces, are light, brittle, of a clean fracture, soft to the touch, of a fine bright blue color, porous, and adhering to the tongue. The lower qualities have a duller color, assume more and more of a reddish tinge, are heavier, more compact, and less easily broken.

The indigo from the upper provinces of India comes chiefly from Tyrool, Oudh, and Benares. It is inferior to Bengal indigo.

Of Madras indigo there are two kinds, viz.: 1. Dry leaf, made from dry stacked leaves; and, 2. Kurpah, which is manufactured from the wet leaf in the same way as Bengal indigo. The latter has only come into use since 1830. Both are of inferior quality to Bengal indigo.

The Manilla indigores present the marks of the rushes upon which they have been dried. The pieces are either cubical, or flat and square, or of irregular shape. The quality is very unequal. Java indigo occurs in flat, square, or lozenge-shaped masses, the quality approaching that of Bengal. Both these kinds are consumed chiefly on the continent of Europe.

Guatemala indigo is imported into this country in bales or hide wrappers, each containing about 130 lbs. It occurs in small irregular pieces, which are more or less brittle, compact, lighter than water, and of a bright blue color, with an occasional tinge of violet. There are three kinds of Guatemala indigo, viz.: 1. Flores, which is the best, and approaches in quality that of the finer Bengal indigoes; 2. Sobres; and, 3. Cortes, which is the lowest in quality, being heavy, difficult to break, and of a coppery-red color. Of the first kind very little now reaches the market. The indigo of Caracocis is, generally speaking, inferior to that of Guatemala.

The manufacture of indigo was formerly carried on in St. Domingo, but has for some time been entirely abandoned.

The indigo of commerce, even when not adulterated, is a mixture of different matters. When it is heated in a state of fine powder to 212° F. it loses from 5 to 10 per cent. in weight, the loss consisting of water. When the dry powder is heated in a crucible a great part burns away, and there is left at last a grayish ash, consisting of the carbonates and phosphates of lime and magnesia, sulphate of lime, alumina, oxide of iron, clay, and sand. These matters are partly derived from the plant, partly from the lime and the impurities of the water employed in the manufacture. The quantity of inorganic matter contained in ordinary indigo varies very much. In the better qualities it amounts on an average to about 10 per cent. of the weight; whilst in the inferior qualities, especially of Madras indigo, it often rises to between 30 and 40 per cent. The organic portion of the indigo, or that which is dissipated when indigo is heated, also consists of several different substances.

By treating indigo with various solvents, Berzelius obtained, besides indigo-blue, the true coloring matter of indigo, three other bodies, viz., indigo-gluten, indigo-brown, and indigo-red, which seem to be contained in various proportions in all kinds of indigo. Indigo-gluten is obtained by treating indigo with dilute sulphuric, muriatic, or acetic acid, and then with boiling water. It is left, on evaporation of its solutions, as a yellow transparent extract, which is soluble in spirits of wine, and easily soluble in water, more difficulty in acid liquids. Its taste is like that of extract of meat. It yields by dry distillation much ammonia and a fettid oil, and behaves in most respects like vegetable gluten. On treating the indigo, after being freed from the indigo-gluten, with hot strong caustic lye, the indigo-brown, together with a little indigo-blue, dissolves, forming a dark brown, almost black solution, from which the indigo-brown, after filtration from the portion insoluble in alkalii, is precipitated by means of acid. After being purified, indigo-brown has the appearance of a dark brown transparent resin, which is almost tasteless and quite neutral. By dry distillation it affords ammonia and empyreumatic oil. It is decomposed by nitric acid and chlorine. It combines both with acids and bases. Its compounds with alkalies are dark brown, and easily soluble in water. The compound with baryta is not easily soluble in water, and that with lime is insoluble. By boiling the alkaline compounds with lime in excess, the indigo-brown may be separated and rendered insoluble. The green sub stance obtained by
Chevreul from indigo seems to have been a compound of indigo-brown with ammonia containing a little indigo-blue, either in a state of combination or mechanically intermingled. Indigo-brown seems to bear a great resemblance, in many of its properties, to the brown resinous substances obtained by Schueck in the decomposition of indigo with acids. From its constant occurrence in all kinds of indigo, it may be inferred that it is not a mere accidental impurity, but stands in some unknown relation to indigo-blue. As long, however, as its origin and composition are unknown, this must remain a mere supposition. After the removal of the indigo-gluten and indigo-brown, the indigo is exhausted with boiling alcohol of specific gravity 0.63. A dark red solution is obtained, which is filtered and distilled, when the indigo-red contained in it is deposited as a blackish-brown powder, which is quite insoluble both in water and in alkaline liquids. Indigo-red, according to Berzelius, is amorphous, but by distillation in vacuo yields a white crystalline sublimate, as well as unchanged indigo-red. Concentrated sulphuric acid dissolves it, forming a dark yellow solution, which deposits nothing on being mixed with water; the diluted solution is rendered colorless by wool, which at the same time acquires a dirty yellowish-brown or red color. The description given by Berzelius leaves it doubtful whether the indigo-red obtained by him from indigo was a pure, unmixed substance. From the leaves of the indigo-tree, as well as from those of the Isatis tinctoria, a substance may, according to Schueck, be extracted, which has received from him the name of ‘indurubine,’ but which seems to be merely indigo-red in a state of purity. This substance has, according to Schueck, the following properties: it crystallizes in small silky needles of a brownish-purple color, which, when rubbed with a hard body, show a slight bronze-like lustre. When carefully heated it may be entirely volatilized, yielding a yellowish-red vapor, which condenses in the form of long plum-colored needles, having a slight metallic lustre. It dissolves in concentrated sulphuric acid, forming a solution of a beautiful purple color, which, when diluted with water yields no deposit and then imparts a fine purple color to cotton, wool, and silk. It is insoluble in water, but dissolves in boiling alcohol with a splendid purple color. It is insoluble in alkalies, but dissolves when exposed to the combined action of alkalies and reducing agents, just as indigo-blue does, forming a solution from which it is again precipitated on exposure to the oxygen of the atmosphere. This solution dyes cotton purple. In most of its properties this body bears a striking resemblance to indigo-blue, and the composition of the two is identical.

It has been doubted whether these various substances or impurities with which indigo-blue is associated produce any effect in the dyeing process on cotton. In a memoir by Schwarzenberg, to which a prize was awarded by the Société Industrielle de Mulhouse, the author arrives at the conclusion that neither indigo-gluten, indigo-brown, nor indigo-red gives rise to any appreciable effect when added to an indigo vat prepared with pure indigo-blue. Nevertheless differences are observable in dyeing with different kinds of indigo, which can only be explained on the supposition that something besides indigo-blue takes part in the process. In the ordinary blue vat, made with copperas and lime, any effect which might be produced in dyeing by the indigo-brown is neutralized by the lime, which forms with it an insoluble compound. Indigo-red, however, dissolves, as mentioned above, in contact with alkalies and reducing agents, and the solution imparts a purple color to cotton. In the ordinary indigo vat its presence may be detected by precipitating a portion of the liquor, and treating the precipitate with boiling alcohol, which then usually acquires a red color. It is possible, therefore, that a small part of the effect produced in dyeing with indigo may be due to indigo-red.

That portion of the indigo which remains after treatment with acid, alkali, and alcohol, consists essentially of indigo-blue, the true coloring matter of indigo, mixed, however, with sand, earthy particles, and other impurities. In order to purify it, the residue, while still moist, is to be mixed with lime, the quantity of which must amount to twice the weight of the crude indigo, and which has been previously shaken with water. The mixture is then put into a bottle capable of holding about 150 times its volume of water, and the bottle is filled up with boiling water and shaken. A quantity of finely powdered protosulphate of iron, amounting to 3 of the weight of the lime is then added, the bottle is closed with a stopper, well shaken, and left to stand for several hours in a warm place. The mass gradually becomes green, and the indigo-blue is then converted by the precipitated protioxide of iron into reduced indigo, which dissolves in the excess of lime, forming a deep yellow solution. This solution when clear is poured off from the deposit into a vessel containing a sufficient quantity of dilute muriatic acid to supersaturate the whole of the lime. The reduced indigo, which is precipitated in greyish-white flocks, is agitation with water until it has become blue, and the regenerated indigo-blue is collected on a filter and washed with water, in order to remove the chloride of calcium and excess of muriatic acid. The following method of obtaining pure indigo-blue has been recommended by Fritzche: 4 oz. of crude indigo and the same weight of grape sugar are put into a bottle capable of holding 12 lbs. of water; a solution of 6 oz. of concentrated caustic soda in alcohol is then added, after which the bottle is filled with hot spirits of wine of 75 per
When on such ceruleo-sulphuric sulphaes, acid none solutions, may of crystalline chlorisatine acids. Fixed with been phuric process. However, small the acid sometimes employed, the latter is employed for imparting a yellow color to silk and wool, but it is generally prepared from cheaper materials than indigo-blue. The action of concentrated sulphuric acid on indigo-blue is very remarkable. The acid is poured on the substance, and gently heated it acquires in the first instance a green color, which changes after some time to blue. No gas of any kind is evolved. When, however, crude indigo is employed, there is a perceptible disengagement of sulphuric acid, resulting from the action of the sulphuric acid on the impurities of the indigo, such as the indigo-gluten, &c. On adding water, a solution of a beautiful deep blue color is obtained. The filtered liquid contains a peculiar acid, to which the names of indigo-sulphure, sulphindigot, sulphindigot, or cereulo-sulphure acid have been applied.

This acid is a so-called double acid. It contains indigo-blue and sulphuric acid, but in such a peculiar state of combination that neither of the two constituents can be detected by ordinary reagents, nor again eliminated as such from the compound. It combines with bases, without either of the two constituents separating. The compounds are called indigo-sulphates, and are, like the acid, of a dark blue color. When the solution of indigo-blue in concentrated sulphuric acid is diluted with water, there is usually formed a small quantity of a dark blue flocculent precipitate, which is the phenicine of Mr. Crum, or the indigo-purple of Berzelius. It is a compound of indigo-blue with sulphuric acid, containing less of the latter than indigo-sulphure acid. It is always formed when the quantity of sulphuric acid employed is not more than eight times that of the indigo-blue, or when the action of the acid on the latter has continued for only a short time. By heating it with an excess of acid it is changed into indigo-sulphure acid. Though soluble in concentrated sulphuric acid, it is insoluble in the dilute acid, and hence is precipitated on the addition of water. On filtering and washing, however, it begins to dissolve as soon as the free sulphuric acid has been removed, and may then be completely dissolved by pure water. The solution has a blue color, just like that of indigo-sulphure acid. Its compounds with bases have a blue color with a purplish tinge. The blue acid liquid filtered from the indigo-purple, on being supersaturated with carbonate of potash or soda, deposits a dark blue powder, which consists of the indigo-sulphate of potash or soda. These compounds are insoluble in water containing a large quantity of neutral salts, and are therefore precipitated when the excess of sulphuric acid is neutralized by carbonate of potash or soda. As soon, however, as the sulphate of potash or soda has been removed by washing, the indigo-sulphate may be dissolved in pure water, yielding a dark blue solution. The indigo-sulphates of the alkalies may also be prepared by steeping wool, previously well cleaned, into the solution in sulphuric acid. The wool takes up the color, becoming of a dark blue color, and after having been well washed with water, in order to remove the excess of acid as well as the impurities which are always present in the solution when crude indigo has been employed, is treated with carbonate of potash, soda, or ammonia, which separate the acid from the wool, and produce blue solutions containing the salts of the respective bases. The indigo-sulphates of the earths and metallic oxides, which are mostly insoluble blue powders, may be obtained from the alkaline salts by double decomposition. By an excess of caustic alkali, indigo-
sulphuric acid is immediately decomposed, giving a yellow solution, from which it is impossible to obtain the acid again. By means of reducing agents, such as sulphured hydrogen, nascent hydrogen, protosulphur of tin and iron, &c., indigo-sulphuric acid is decolorized, but the color is restored by the oxygen of the atmosphere. Indigo-sulphuric acid, in a free state or in combination with alkalies, is employed in the arts for the purpose of imparting a blue color to silk and wool. It has very little affinity for cotton fibre, but is nevertheless employed occasionally for bleaching white cotton-yarn and other bleached goods.

By treatment with strong boiling caustic potash or soda lye, indigo-blue is gradually decomposed and converted into a colorless crystallized acid, anthraquinone acid. By weak solutions of caustic alkalis, it is not in the least affected. If, however, it be subjected to the combined action of an alkali or alkaline earth and some body having a strong affinity for oxygen, such as protoxide of iron or tin, sulphur, phosphorus or phosphoric acid, or organic matters, such as grape-sugar, &c., it disappears by degrees, yielding a yellow solution, containing in the place of indigo-blue another substance, which has been called indigo-white, indigogene, or reduced indigo. When an excess of some acid is added to the yellow solution, the indigo-white is precipitated in white or grayish-white flocks, which on filtration and exposure to the atmosphere rapidly become blue, and are reconverted into indigo-blue. Indigo-white is insoluble in water, but slightly soluble in alcohol. It is soluble in caustic alkalis, lime, and baryta water. The solutions, on exposure to oxygen, become covered with a pellicle of regenerated indigo-blue. With an excess of lime it gives an insoluble compound. Its compounds with alumina and metallic oxides, which are insoluble in water, may be obtained by double decomposition. Salts of oxide of copper, when added to its solutions in alkali, convert it immediately into indigo-blue, the oxide of copper being reduced to suboxide. Indigo-blue is also converted into indigo-white when it is exposed to the action of fermenting or putrefying substances, in the presence of water. Here the decomposing organic matter is the reducing agent, and ammonia, which is usually formed during the process of putrefaction, is the solvent of the indigo-white. If a piece of cotton, wool, or silk be dipped into an alkaline solution of indigo-white and then exposed to the atmosphere, it acquires a blue color, which may be made deeper by repeated dippings and subsequent exposure. It is on this property of indigo-white that the dyeing with indigo depends.

The true chemical formula of indigo-blue, which was first discovered by Mr. Crum, is C\textsubscript{16}H\textsubscript{14}N\textsubscript{2}O\textsubscript{3}, and 100 parts contain therefore by calculation 73.28 carbon, 3.81 hydrogen, 10.68 nitrogen, and 12.23 oxygen. The formula of indigo-white is C\textsubscript{6}H\textsubscript{4}N\textsubscript{2}O\textsubscript{6}, and it differs therefore from indigo-blue by containing 1 atom more of hydrogen, which is taken up during the so-called reduction of the latter, and lost again by oxidation during its reconversion into indigo-blue.

Since the value of indigo depends entirely on the quantity of indigo-blue which it contains, it is of great importance to ascertain the exact amount of the latter in any given sample of the article. Before commencing the determination of the indigo-blue, a weighed portion of the indigo ought to be heated for some hours at 212° F., and then weighed again. The loss in weight which takes place represents the amount of water contained in the sample. A weighed quantity of the dried indigo is then to be heated over the flame of a bunsen until all the organic matter has been burnt away. By weighing the residue which is left the amount of ash or inorganic matter is ascertained. In order, in the next place, to determine the amount of indigo-blue, several methods have been devised by various chemists, none of which, however, yield very accurate results. Of these methods the following are the principal ones:

1. A weighed quantity of finely powdered indigo is rubbed with water in a porcelain mortar. An equal weight of pure lime is then slaked with water, and the hydrate is well mixed with the indigo. The mixture is then poured into a stopped bottle of known capacity, and the mortar is well rinsed with water, which is added to the rest. The bottle is now heated in a water-bath for several hours, and a quantity of finely powdered sulphate of iron is added; the bottle is then filled up with water, the stopper is inserted, and after the contents have been well shaken the whole is allowed to repose for some hours, until the indigo has been reduced and the sediment has sunk to the bottom. A portion of the clear liquor is then drawn off with a pipet, and the quantity of liquid having been accurately measured, it is mixed with an excess of muriatic acid, and the precipitate, after having been oxidized, is collected on a weighed filter and well washed with water. Lastly, the filter with the indigo-blue is dried at 212° F. and weighed, and the weight of the filter having been subtracted from that of the whole, the weight of the indigo-blue is ascertained. Supposing now that the whole quantity of liquid had been 200 measures, that 50 measures had been drawn off yielding 10 grains of indigo-blue, then the sample contained on the whole 40 grains of the latter. For 60 grains of indigo it is necessary to take from 360 to 2 lbs. of water.

According to Mr. John Dale, of Manchester, who has had great experience in the valuation of indigo for practical purposes, this method, though rather long and tedious, still
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It gives more accurate results than any other. The quantity of indigo-blue indicated by it is generally below the actual quantity contained in the sample. According to Berzellius this loss arises from the lime forming an insoluble compound with a portion of the reduced indigo-blue. Mr. Dale, however, is of opinion, that even when every precaution has been taken, a certain loss, proceeding from some hitherto unascertained cause, cannot be avoided.

When, for instance, pure indigo-blue is treated with lime and copperas in the manner just described, the quantity which is again obtained by precipitation from any portion of the liquid is always less than what it should be by calculation, even when no excess of lime has been employed.

2. The second method of determining the indigo-blue is performed as follows:—About 15 or 20 grains of pure indigo-blue, obtained by precipitation from an indigo vat, and the same quantity of the indigo to be tested, which must be previously ground to a fine powder, are weighed off, and each of them is treated with about 12 times its weight of concentrated sulphuric acid in a flask or porcelain basin. After being heated at a temperature of 120° to 140° F. for about 24 hours, and occasionally well agitated, the two liquids are mixed with water, so that the volume of the two shall be exactly equal. Two equal measures of a weak solution of hypochlorite of lime are then taken, and to the first is added a quantity of the solution of pure indigo. The chlorine liberated by the excess of sulphuric acid in the solution destroys the blue color of the indigo-sulphuric acid. More of the solution must be added until the liquid begins to acquire a greenish tinge, and the number of measures necessary for the purpose is noted. The same experiment is then made with the solution of crude indigo. The quantity of indigo-blue in the latter is, of course, in inverse ratio to the number of measures which are requisite in order to take up the whole of the chlorine which is liberated. If, for example, the same quantity of hypochlorite of lime decolorizes 167 measures of the solution of pure indigo-blue and 204 measures of the solution of crude indigo, then the quantity of indigo-blue contained in 100 parts of the latter is given by the following proportion—204 : 167 :: 100 : x = 81-8.

A number of samples of indigo may be tested in this manner at the same time. Care must be taken to prepare a fresh solution of indigo-blue for every series of trials, since this solution undergoes a change on standing, which renders it quite inapplicable as a standard of comparison. It is necessary also to pay great attention at the moment when the greenish color indicating an excess of the sulphate of indigo begins to appear, for it will often be found that this color disappears after standing a few minutes, and a fresh quantity of the blue solution must then be added cautiously, until the greenish tinge becomes permanent, even after standing for some time. Modifications of this process have been introduced by various chemists by the use of permanganate of potash, chlorate of potash, or bichromate of potash, in the place of hypochlorite of lime: but as the principle on which the process depends is in each case identical and the modus operandi is almost the same, it will be unnecessary to enter into any minute description of these modifications. The whole method is, however, open to serious objections, and the results which it affords cannot at all be depended on. In the first place, it is difficult to institute a strict comparison between the different shades of color resulting from the decomposition of the sulphate of indigo in different cases, since the pure green tinge observed when an excess of the pure sulphate has been added to the decomposing agent, gives place to a dirty olive or brownish-green, when a solution of crude indigo is employed, in consequence of the impurities contained in the latter. Secondly, it is almost impossible to avoid the formation of a certain quantity of sulphurous acid during the action of concentrated sulphuric acid on crude indigo. This sulphurous acid during the following operation becomes oxidized before the blue sulphate is destroyed, and hence the percentage of indigo-blue is apparently raised. In employing this method, it is common to find more than 80 per cent. of indigo-blue in a good sample of indigo, whereas the best qualities seldom contain above 60 per cent., and average qualities between 40 and 50 per cent. This method may show a percentage of 70 indigo-blue, when the method first described indicates between 50 and 60.

3. The third method of estimating the indigo-blue is performed in the following manner: Equal weights of the samples to be tested are treated with equal quantities of concentrated sulphuric acid in the manner above described, and the solutions are then diluted with water and introduced into graduated glass cylinders, water being added to each until they all exhibit exactly the same shade of color. The richer the sample is in indigo-blue, the greater will be the quantity of water necessary for this purpose, the number of measures of water required in each case indicating the relative amount. The great objection to this method consists in the circumstance, that the different kinds of indigo do not give the same shade of blue when their solutions in sulphuric acid are diluted with water, some exhibiting a pure blue color, others a blue with a greenish or purplish tinge. It therefore becomes difficult to institute an exact comparison between them.

The ingredients necessary for setting the vat are copperas or protoxyline of iron, newly slaked quicklime, and water. Various proportions of these ingredients are employed, as for instance, 1 part by weight of indigo, (dry,) 3 parts of copperas, and 4 of lime; or 1
of indigo, 2 1/2 of copperas, and 3 of lime; or 8 of indigo, 14 of copperas, and 20 of lime; or 1 of indigo, 1/4 of copperas, and 1 of lime. The sulphate of iron should be as free as possible from the red oxide of iron, as well as from sulphate of copper, which would re-oxidize the reduced indigo-blue. The vat having been filled with water to near the top, the materials are introduced, and the whole after being well stirred several times is left to stand for about twelve hours. The chemical action which takes place is very simple. The protioxide of iron which is set at liberty by the lime reduces the indigo-blue, and the indigo-white is then dissolved by the excess of lime, forming a solution, which, on being examined in a glass, appears perfectly transparent and of a pure yellow color, and becomes covered wherever it comes into contact with the air, with a copper-colored pellicle of regenerated indigo-blue. The solution at the bottom of the vat consists of sulphate of lime, peroxide of iron, and the insoluble impurities of the indigo, such as indigo-brown in combination with lime, as well as sand, clay, &c. If an excess of lime is present, a little reduced indigo-blue will also be found in the sediment in combination with lime.

The copperas vat is employed in dyeing cotton, linen, and silk. For cotton goods no other kind of vat is used at the present day. The dyeing process itself is very simple. The vat having been allowed to settle, the goods are plunged into the clear liquor, and after being gently moved about in it for some time are taken out, allowed to drain, and exposed to the action of the atmosphere. Whilst in the liquid the fabric attracts a portion of the reduced indigo-blue. On now removing it from the liquid it appears green, but soon becomes blue on exposure to the air in consequence of the oxidation of the reduced indigo-blue. On again plunging it into the vat, the deoxidizing action of the latter does not again remove the indigo-blue which has been deposited within and around the vegetable or animal fibre, but on the contrary, a fresh portion of reduced indigo-blue is attracted, which on removal from the liquid is again oxidized like the first, and the color thus becomes a shade darker. By repeating this process several times, the requisite depth of color is attained. This effect cannot in any case be produced by one immersion in the vat, however strong it may be. The beauty of the color is increased by finally passing the goods through diluted sulphuric or muriatic acid, which removes the adhering lime and oxide of iron. After being used for some time the vat should be refreshed or fed with copperas and lime, upon which occasion the sediment must first be stirred up, and then allowed to settle again, so as to leave the liquor clear. The indigo-blue, however, is in course of time gradually removed, and by degrees the vat becomes capable of dyeing only pale shades of blue. When the color produced by it is only very faint, it is no longer worth while using it, and the contents are then thrown away. In dyeing cotton with indigo, it seems to be essential that the reduced indigo-blue should be in combination with lime. If potash or soda be used in its stead, it is impossible to obtain dark shades of blue.

When cotton piece goods are to be dyed of a uniform blue, they are not submitted to any preparatory process of bleaching or washing. Indeed the size contained in unbleached goods seems rather to facilitate than to impede the dyeing process. In dyeing these goods a peculiar roller apparatus is employed. When certain portions of the fabric are to retain their white color a different plan is adopted. The pieces having been bleached, those portions which are to remain white are printed with so-called resist. These resists consist essentially of some salt of copper, mixed with an appropriate thickening material. The copper salt acts by oxidizing the reduced indigo-blue at the surface, and thus rendering it insoluble before it can enter into the interior of the vegetable fibre, since it is only when deposited within the fibre itself that the coloring matter becomes durably fixed. The pieces are now stretched upon square dipping frames, made of wood or of iron, furnished with sharp hooks or points of attachment. These frames are suspended by cords over a pulley, and thus immersed and lifted out alternately at proper intervals. In dyeing, a set of 10 vats is used, the first vat containing 5 or 6 lbs. of indigo, and the quantity increasing gradually up to 80 lbs. in the last vat. The pieces are dipped for 7/4 minutes in the first vat, then taken out and exposed to the air for the same length of time, then dipped in the second vat, and so on to the last. After passing through the last vat, a small bit of the calico is dried, in order to see whether the color is sufficiently dark. If it is not, the whole series must be dipped once more in the same vat in which the last dipping was performed. When the bottom of the vat is racked up so as to have more lime in suspension, the vat becomes what the dyer calls hard, that is to say, the oxide of copper of the resist is precipitated in a compact state, and consequently acts with more efficiency. But when the vat has been at rest for some time, and there is little lime in suspension, then it is called soft. When it is in this state, the oxide of copper is thrown down in a bulky form, and when the pieces are afterwards agitated in the liquor, in order to detach the oxide of iron, which always floats about in the vat, and attaches itself to the fabric, and which if left adhering would cause light stains, technically called grounding; then the oxide of copper is also detached, and the indigo penetrates to those parts which remain white. When cotton yarn is dyed in the copperas vat, the latter is generally heated by means of steam pipes passing through the liquor, the object being to give to the color the peculiar gloss or lustre, which is required in this class of goods. No
INDIGO.

preparatory process is required, except simply steeping in hot water. In dyeing, wooden pins are put through the hanks, their ends resting on supports passing over the top of the vat, and the yarn is then slowly turned over, one half being in the liquor, the other half over the pins. It is then taken out, wrung, exposed to the air, and again dipped, this operation being repeated until the requisite shade is obtained.

The methods employed for producing the colors called China blue and penicil blue on cotton have been described under Calico Printings.

Woad vat.—In former times, woad was the only material known to the dyers of Europe for producing the blue color of indigo. For this purpose it was previously submitted to a peculiar process of fermentation, and the product was named pastel in France. For most purposes indigo has taken the place of woad in the dye-house, and for cotton goods it is now used alone. In the dyeing of woollen goods, however, the use of woad has been retained to the present day, for the purpose rather of exciting fermentation and thus reducing the indigo which is employed at the same time, than of imparting any color to the material to be dyed. Indeed, the woad used by woollen dyers in this country contains no trace of coloring matter. Various substances, such as rhubarb leaves, turnip tops, weld, and other vegetable matters, have accordingly been tried, but without success, since the fermentation is more readily maintained by means of woad than by any other material. Pastel, which does contain a little blue coloring matter, is preferred to woad by many of the French dyers.

The materials employed in the ordinary woad or pastel vat, in addition to woad and indigo, are madder, bran, and lime. In the so-called Indian or potash vat, madder, bran, and carbonate of potash are used; in the German vat, bran, carbonate of soda, and quicklime, without woad. The chemical action which takes place in the woad vat is not difficult to understand. The nitrogenous matters of the woad begin, when the temperature is raised, to enter into a state of fermentation, which is kept up by means of the sugar, starch, extractive matter, &c., of the madder and bran. In consequence of the fermentation, the indigo-blue becomes reduced, and is then dissolved by the lime, thus rendering the liquid fit for dyeing. Great care is necessary in order to prevent the process of fermentation from passing into one of putrefaction, which if allowed to proceed would lead to the entire destruction of the indigo-blue in the liquor. If any tendency to do so is observed, it is arrested by the addition of lime, which combines with the acetie, laetic, and other organic acids that commence to form when putrefaction sets in. On the other hand, an excess of lime must also be avoided, since the reduced indigo-blue is thereby rendered insoluble, and unfit to combine with the material.

The following account of the method of dyeing woollen goods with indigo, as carried on at present in Yorkshire, may suffice to give a general idea of the process:

The dye-vats employed are circular, having a diameter of 6 feet 6 inches, and a depth of 7 feet, and are made of cast iron 3 of an inch in thickness. They are surrounded by brickwork, a space of 3 inches in width being left between the brickwork and the iron, for the purpose of admitting steam, by means of which the vats are heated. The interior surface of the iron vats is well cemented. In setting a vat the following materials are used: 5 cwt. of woad, 30 lbs. of indigo, 56 lbs. of bran, 7 lbs. of madder, and 10 quarts of lime. The woad supplied to the Yorkshire dyers is grown and prepared in Lincolnshire. It is in the form of a thick brownish-yellow paste, having a strong ammoniacal smell. The indigo is ground with water in the usual manner. The madder acts in promoting fermentation, but it also serves to give a reddish tinge to the color. The lime is prepared by putting quicklime into a basket, then dipping it in water for an instant, lifting it out again, and then passing it through a sieve, by which means it is reduced to a fine powder, called by the dyers whee.

The vat is first filled with water, which is heated to 140° Fahr., after which the materials are put in, and the whole is well stirred until the water is dissolved or diffused, and it is then left to stand undisturbed over night. At 6 o'clock the next morning the liquor is again stirred up, and 5 quarts more lime are added. At 10 o'clock, 9 pints of lime are again thrown in, and at 12 o'clock the heat is raised to 120° Fahr., which temperature must be kept up until 3 o'clock, when another quart of lime is introduced. The vat is now ready for dyeing. When the process of fermentation is proceeding in a regular manner, the liquid, though muddy from insoluble vegetable matter in suspension, is of a yellow or olive-yellow color; its surface is covered with a blue froth or a copper-colored pellicle, and it exudes a peculiar ammoniacal color; at the bottom of the vat there is a mass of undissolved matter, of a dirty yellow color. If there is an excess of lime present, the liquor has a dark green color, and is covered with a grayish film, and when agitated, the bubbles which are formed agglomerate on the surface, and are not easily broken. Cloth dyed in a liquor of this kind loses its color on being washed. This state of the vat is remedied by the addition of bran, and is of no serious consequence. When, on the other hand, there is a deficiency of lime, or in other words, when the fermentation is too active, the liquor acquires first a drab, then a clay-like color; when agitated, the bubbles which form on its surface burst easily, and when stirred up from the bottom with a rake it effervescs slightly, or sritis, as the dyers say. If the fermentation be not checked at this stage, putrefaction soon acts
in, the liquid begins to exhale a feebil odor, and when stirred evolves large quantities of gas, which burn with a blue flame on the application of a light. The iodine is now totally destroyed, and the contents of the vat may be thrown away. No further addition of wood is required after the introduction of the quantity taken in first setting the vat, the fermentation being kept up by adding daily about 4 lbs. of bran, together with 1 quart or 3 pints of lime. Indigo is also added daily for about three or four months. The vat is then used for the purpose of dyeing light shades, until the indigo contained in it is quite exhausted, and its contents are then thrown away.

Woollen cloth, before being dyed, is boiled in water for one hour, then passed immediately into cold water. If it be suffered to lie in heaps immediately after being boiled, it undergoes some change, which renders it afterwards incapable of taking up color in the vat. When a purple bloom is required on the cloth, it is dyed with cudbear to a light purple shade before being dipped. In dyeing, the cloth is placed on a network of rope attached to an iron ring, which is suspended by four iron chains at a depth of about 3 feet beneath the surface of the liquor. The cloth is stirred about in the liquor by means of hooks for about 20 or 30 minutes. It is then taken out and well wrung. It now appears green, but on being unfolded and exposed to the air rapidly becomes blue. When the vat contains an excess of lime the cloth has a dark green color when taken out. It is then passed through hot water and dipped again, if a darker shade is required. When woollen flocks are to be dyed, they are placed in a net made of cord, which is suspended by hooks at the side of the vat. They are then transferred to a stronger net and wrung out by several men. In dyeing flocks a more active fermentation of the vat is required than with cloth.

The process of dyeing by means of sulphate of indigo is quite different from indigo dyeing in the vat. This process was discovered by Barth, at Grossenbayn in Saxony, about the year 1740, and the color produced by it is hence called Saxo blue. The method of purifying sulphate of indigo, by immersing wool in the solution of crude indigo in oil of vitriol, previously diluted with water, has been described above. The process of making sulphate of indigo or extract of indigo, as it is called, as now practised on the large scale, is as follows:—1 lb. of indigo is mixed with from 8 to 9 lbs. of oil of vitriol, and the mixture is left to stand for some hours in a room, the temperature of which is 90° Fahr. It is then diluted with water, and filtered through paper. There is left on the filter a dirty olive-colored residue, which is used for some purposes by woollen dyers. By now adding common salt to the liquid, a blue precipitate of sulphate of indigo is produced, which is collected on a filter, and washed with a solution of salt in order to remove the excess of acid. No neutralization with alkali is required when this plan is pursued. The blue produced on wool and silk by means of sulphate of indigo is very fugitive, and is now seldom required, its place having been in a great measure taken by the blue from prussiate of potash. The chief use of sulphate of indigo is for dyeing compound colors, such as green, olive, gray, &c.—E. S.

iodin (iod, Fr.; Joh, Germ.) is one of the elementary substances; it was accidentally discovered in 1812 by M. Courtois, a manufacturer of saltpetre at Paris. He found that, in the manufacture of soda from the ashes of sea-weeds, the metallic vessels in which the processes were conducted became much corroded; and in searching for the cause of the corrosion, he discovered this now important substance. It was first described by Clement in 1813, but was afterwards more fully investigated by Davy and Gay-Lussac. Gay-Lussac and Clement at first looked upon hydriodic acid as hydrochloric acid, until Sir H. Davy suggested the idea of its being a new and peculiar acid, and iodine as a substance analogous in its chemical relations to chlorine.

It was named iodine from the Greek word ἰόδων, violet-colored, on account of the color of its vapor.

Iodine exists in many mineral waters in combination with potassium and sodium.

In the mineral kingdom, iodine has been found in one or two rare ores, as in a mineral brought from Mexico, in which it existed in combination with silver, and also in one from Silesia in combination with zinc.

It exists also in very small quantities in sea water, from which it is extracted by many sea-weeds, which act therefore as concentrators of iodine; these sea-weeds when dried and ignited yield an ash, technically called kelp, from which all the soda of commerce was previously obtained, but the chief value of the kelp now is on account of the iodine which it yields. The following is the process most generally adopted for the extraction of the iodine from the sea-weeds:

The sun-dried sea-weed is incinerated in shallow excavations at a low temperature, for if the temperature was allowed to rise too high a considerable quantity of iodide of sodium would be lost by volatilization. The half-fused ash or kelp which remains is broken into fragments, and treated with boiling water, which dissolves about one-half of the ash.

The liquid thus obtained is evaporated, when on cooling the more crystalizable salts
separate, viz., sulphate and carbonate of soda, with some chloride of potassium. The mother liquor still contains the iodide of sodium, sulphide of sodium, sulphide and carbonate of soda. This liquor is then mixed with about one-eighth of its bulk of sulphuric acid, and allowed to stand for twenty-four hours; carbonic and sulphurous acid and sulphuretted hydrogen gases escape, a fresh quantity of sulphate of soda crystallizing out, mixed with a precipitate of sulphur.

The supernatant acid liquor is then transferred to a leaden still, to which is adapted a double tubulated leaden head luted on with pipe-clay; it is then heated to 110° F., when binoxide of manganese is added.

The temperature may be gently raised to 212° F., but not higher, as some chlorine would come over, and combine with some of the iodine, forming chloride of iodine.

The iodine is condensed in spherical glass condensers, each having two months opposite to each other, and inserted the one into the other, the end one being fitted to the neck of the leaden head.

The iodine is purified by resublimation.

The following formula represents the reaction:

\[ \text{Iodide of Oxide of Sulphur} + \text{Sulphate of Sodium} = \text{Water.} \]

\[ \text{Soda} + \text{Manganese.} \]

\[ \text{NaI} + \text{MnO}_2 + 2\text{H}_2\text{SO}_4 = \text{Na}_2\text{SO}_4 + \text{MnSO}_4 + \text{I} + 2\text{H}_2\text{O} \]

The British iodine is exclusively manufactured at Glasgow, from the kelp of the west coast of Ireland and the western islands of Scotland.

Iodine is a crystalizable solid, its primary form being a rhombic octaehedron. It is however usually met with in melaconous, soft, friable scales, having a grayish-black color, a metallic lustre, and an acrid hot taste. Even at ordinary temperatures, and more especially when moist, it is sensibly volatile, emitting an odor like that of chlorine, only much weaker.

At 225° F. it fuses, and at 347° F. boils, and is converted into a magnificent violet vapor. It may nevertheless be distilled, in the presence of steam, at a temperature of 212°, as is seen in the process of manufacture.

Iodine, in the solid state, has a specific gravity of 4.947, the specific gravity of the vapor being, according to Dumas, 8.716. Iodine is only very slightly soluble in water, it requiring 7,000 parts of water to dissolve it; even then it imparts a yellow color to the solution, and is used in that state as a test for starch, with which it forms a beautiful blue compound, which is, however, destroyed by heat.

Alcohol and ether dissolve it more readily; but the most powerful solvents of iodine are the solutions of the iodides. Iodine stains the skin, and most organic substances, of a brown color; it attacks the metals rapidly, iron or zinc being readily dissolved by it if placed in water with it, an iodide of the metal being formed.

All the compounds of iodine with the metals and with hydrogen are decomposed by chlorine, and even by bromine, iodine being set free. Advantage is taken of this fact in detecting the presence of iodine. If the iodine exists in combination with a metal, or as hydriodic acid, its solution will not form the characteristic intense blue compound with starch, but on the addition of a little chlorine, or solution of bleaching-powder, the iodine is set free and forms the blue compound with the starch. If, however, the iodine exists as iodic acid, it will not act upon starch unless reduced by some reducing agent, as sulphurous acid. In using the chlorine care must be taken not to use too much, as it would unite with the iodine and prevent it acting on the starch.

Iodine is used to a considerable extent in medicine; when taken in large doses it is an irritant poison, but in small doses it is a most valuable medicine, particularly in glandular swellings, and in certain forms of goitre. It is also much used in photography. The chemical symbol for iodine is I; its equivalent number 126.88; and the combining volume of its vapor 2.—H. K. B.

IRON.

The modern processes of iron-smelting differ materially according as the fuel employed is charcoal or pit-coal. As an illustration of the method adopted when the former is used, the following details of the manufacture of the celebrated "Oeregrund iron" may be taken, premising that the operations vary in a few particulars in other countries where different kinds of ore are dealt with. The Oeregrund iron is made from the magnetic ironstone of Dannemora in Sweden. The ore, in moderately large pieces, such as it comes from the mine, is first roasted. For this purpose an oblong coffer of masonry, 18 feet long, 15 feet wide, and about 6 feet in depth, open at top, and furnished with a door at one of its smaller extremities, is entirely filled with logs of wood; over this the ore is piled to the height of from 5 to 7 feet, and is covered with a coating of small charcoal, almost a foot and a half in thickness. Fire is then communicated to the bottom of the pile, by means of the door just mentioned, and in a short time the combustion spreads through the whole mass; the small quantity of pyrites that the ore contains is decomposed by the volatilization of the sulphur; the moisture is also driven off, and the ore, from being very hard and refractory, becomes pretty easily pulverizable.
In the space of twenty-four hours the roasting is completed; and the ore when sufficiently cool is transferred to a stamping-mill, where it is pounded dry, and afterwards sifted through a network of iron, which will not admit any piece larger than a hazel-nut to pass. It is now ready to be smelted. The smelting-furnace is a strong quadrangular pile of masonry, the internal form of which, though simple in form, is not very easily described. It may be considered in general as representing two irregular truncated cones, joined base to base; of these the lower is scarcely more than one-third of the upper, and is pierced by two openings, through the upper end of which the blast of wind from the blowing machine is admitted into the furnace; and from the latter the melted matter, both scoria and metal, is discharged from time to time at the pleasure of the workmen.

The furnace is first filled with charcoal alone, and well heated, after which alternate charges are added of ore, either alone or mixed with limestone (if it requires any flux) and charcoal; the blast is let on, and the metal in the ore being highly carbonized in its passage through the upper part of the furnace, is readily melted as soon as it arrives in the focus of the blast, whence it subsides in a fluid state to the bottom of the furnace, covered with a melted slag. Part of the clay that closes the lower aperture of the furnace is occasionally removed, to allow the scoria to flow out, and at the end of every ninth hour the iron itself is discharged into a bed of sand, where it forms from ten to twelve small pigs. As soon as the iron has flowed out, the aperture is closed again, and thus the furnace is kept in incessant activity during the first six months of the year; the other six months are employed in repairing the furnaces, making charcoal, and collecting the requisite provision of wood and ore. The next process for converting the pig into bar iron is refining; for this purpose a furnace is made use of, resembling a smith's hearth, with a sloping cavity, sunk from ten to twelve inches below the level of the blast-pipe. This cavity is filled with charcoal and scorion, and on the side opposite to the blast-pipe is laid a pig of cast iron well covered with hot fuel. The blast is then let in, and the pig of iron, being placed in the very focus of the heat, soon begins to melt, and as it liquefies, runs down into the cavity below; here, being out of the direct influence of the blast, it becomes solid, and is then taken out, and replaced in its former position. The cavity being then filled with charcoal, it is thus fused a second time, and after that a third time, the whole of these three processes being usually effected in between three and four hours. As soon as the iron has become solid it is taken out, and very slightly hammered to free it from the adhering scorion: it is then returned to the furnace, and placed in a corner, out of the way of the blast, and well covered with charcoal, where it remains, till, by further gradual cooling, it becomes sufficiently compact to bear the till hammer. Here it is well beaten till the scoria are forced out, and it is then divided into several pieces, which, by a repetition of heating and hammering, are drawn into bars, and in this state is ready for sale. The proportion of pig iron obtained from a given quantity of ore is subject to considerable variation, from the difference in the metallic contents of different parcels of ore and other circumstances; but the amount of bar iron that a given weight of pig metal is expected to yield is regulated very strictly, the workmen being expected to furnish four parts of the former for five parts of the latter, so that the loss does not exceed 20 per cent.

In some parts of America, particularly in the States of Vermont and New Jersey, the Catalun forge is extensively employed for smelting the rich magnetic ores which there abound. The furnace, which is nearly uniform everywhere, and the manipulation with it in America, is thus described by Overman:—The whole is a level hearth of stone work, from 6 to 8 feet square, at the corner of which is the fireplace, from 24 to 30 inches square, and from 15 to 18, often 20, inches deep. Inside it is lined with cast-iron plates, the bottom plate being from 2 to 3 inches thick. Figure 332 represents a cross section through the fireplace and tuyere, commonly called theue iron; d represents the fireplace, which, as remarked above, is of various dimensions. The tuyere or b is from 7 to 8 inches above the bottom, and more or less inclined according to circumstances. The blast is produced by wooden hollows of the common form, or more generally by square wooden cylinders, urged by water-wheels. The ore chiefly employed is the crystallized magnetic ore. This ore very readily falls to a coarse sand, and when roasted varies from the size of a pea to the size of a grain. Some of it is roasted only a third of the time the ore is employed without roasting. In the working of such fires much depends on the skill and experience of the workman. The result is subject to considerable variation, that is, whether economy of coal or that of ore is our object. Thus a modification
is required in the construction either of the whole apparatus or in parts of it. The manipulation varies in many respects. One workman, by inclining his tuyere to the bottom, saves coal at the expense of obtaining a poor yield. Another, by carrying his tuye iron more horizontally at the commencement, obtains a larger amount of iron, though at the sacrifice of coal. Good workmen pay great attention to the tuyere, and alter its dip according to the state of the operation. The general manipulation is as follows:—The hearth is lined with a good coating of charcoal dust; and the fire plate, or the plate opposite the blast, is lined with coarse ore, in case any is at our disposal. If no coarse ore is employed, the hearth is filled with coal, and the small ore piled against a dam of coal dust opposite the tuyere. The blast is at first urged gently, and directed upon the ore, while the coal above the tuyere is kept cool. Four hundred pounds of ore are the common charge, two-thirds of which are thus smelted, and the remaining third, generally the finest ore, is held in reserve, to be thrown on the charcoal when the fire becomes too brick. The charcoal is piled to the height of two, sometimes even three and four feet, according to the amount of ore to be smelted. When the blast has been applied for an hour and a half or two hours, most of the iron is melted, and forms a pasty mass at the bottom of the hearth. The blast may now be urged more strongly, and if any pasty or spongy mass yet remains, it may be brought within the range of the blast and melted down. In a short time the iron is revived, and the scoriae are permitted to flow through the tapping hole, so that but a small quantity of cinder remains at the bottom. By means of iron bars, the lump of pasty iron is brought before the tuyere. If the iron is too pasty to be lifted, the tuyere is made to dip into the hearth; in this way the iron is raised from the bottom, directly before, or to a point above the tuyere, until it is welded into a coherent ball, twelve or fifteen inches in diameter. This ball is brought to the hammer or squeezer, and shingled into a bloom, which is either cut in pieces to be stretched by a hammer, or sent to the rolling-mill to be formed into marketable bar iron. A mixture of fibrous iron, cast iron, and steel, is the result of the above process; the quality of the iron depends entirely on the quality of the ore, for there are no opportunities for the exercise of any skill to create improvements in the process; poor ores cannot be smelted at all. In Vermont, where the rich magnetic ores are employed, a ton of blooms costs about 40 dollars; 4 tons of ore and 300 bushels of charcoal are required to produce 1 ton of blooms. The fournaux à pièce of the French, or Stick-ofen of the Germans, holds a place intermediate between the Cæcum hearth and the high blast furnace now in general use. The iron produced in this kind of furnace is generally of a very superior kind, but it is very little in use at the present time, on account of the great expense of its manipulation. The Stick-ofen, or Salamander furnace, as it is sometimes called, is a small cupola, its interior having the form of a double crucible. It is usually from 10 to 16 feet high, and 24 inches wide at bottom and top; and measures at its widest part about 5 feet. There are generally two tuyeres, both on the same side; the breast is open, but during the smelting operation it is shut by bricks. The furnace is heated previous to closing in the breast; after which charcoal and ore are thrown in; the blast is then turned on; as soon as the ore passes the tuyère, iron is deposited at the bottom of the hearth; when the cinder rises to the tuyere, a portion is suffered to escape through a hole in the dam; the tuyeres are generally kept low upon the surface of the melted iron, which thus becomes whitened; as the iron rises, the tuyeres are raised. In about 24 hours one ton of iron is deposited at the bottom of the furnace, the blast is turned off, and the iron, which is in a solid mass, in the form of a salamander, or Stick wolf, as the Germans call it, is lifted loose from the bottom by crowbars, taken by a pair of strong tongs, which are fastened on chains, suspended on a swing crane, and then removed to an anvil, where it is flattened by a tilt hammer into
four-inch thick slabs, cut into blooms, and finally stretched into bar iron by smaller hammers. Meanwhile the furnace is charged anew with ore and coal, and the same process is renewed. This process, as well as that of the Catalan hearth, is impracticable with ores containing much foreign matter, or less than 40 per cent. of metal.

The general form of the modern charcoal blast furnace, as used in the United States, where this fuel is far more common than pit-coal, (indeed, it is doubtful whether any coke furnaces are at the present time in operation in that country,) is shown in vertical section in fig. 333, and in section through the tuyere arches in fig. 334. The ores designed to be smelted in this furnace are hydrated oxides of iron, such as brown hematite, brown iron stone, pipe ore, and bog ores. The height is 35 feet; hearth from base to the boshes, 5 feet, 6 inches; width at the bottom, 24 inches; and at top, 26 inches. The tuyeres are 20 inches above the base. The boshes are 5 feet 6 inches in diameter, and measure from the top of the crucible 4 feet, which gives about 60° slope. The blast is conducted through sheet-iron or cast-iron pipes laid below the bottom stone into the tuyeres. The top is furnished with a chimney, by which the blaze from the tunnel head is drawn off. Around the top is a fence of iron or wood. Fig. 335 shows the method of preparing and arranging the hearth-stones. a is the bottom stone, made of a fine close-grained sand-stone, from 12 to 15 inches thick, at least 4 feet wide, and 6 feet long; it reaches underneath at least half of the dam-stone b. This bottom stone is well bedded in fire-clay, mixed with three-fourths sand. After the bottom stone is placed, the upper part of which must be three-fourths of an inch lower at the dam-stone than at the back, the two side stones c, are laid embedded in fire-clay. These stones must be at least 6 feet and a half long, reaching from 18 inches behind the crucible to the middle of the dam-stone. Their form is most commonly square, that is, a prism of four equal sides; the transverse section of the grain must be in all cases placed towards the fire; the side stones are sometimes square, but oftener bevelled according to the slope of the hearth. Upon these stones the tuyere stones d are bedded; the latter suffer much from heat, and therefore ought to be of the best quality. They should be from 20 to 24 inches square, or even larger; the tuyere holes e, a kind of taper arch, are cut out before the stones are bedded. These stones do not reach further than to the front or timpstone g, and are therefore scarcely four feet long; the top stone f, is generally sufficiently high to raise at once the crucible to its destined height. After both sides are finished the back stone f is put in, and then the timpstone g; the space between the hearthstones and the rough wall of the furnace stack is filled and walled up with common brick or stones.
In starting a charcoal furnace, it is first thoroughly dried by burning a fire for several weeks in the interior, which has a temporary lining of bricks. The lower part of the furnace or the hearth is then filled gradually with charcoal, and when the fuel is well ignited, and the furnace half filled, ore may be charged in; it is sometimes advisable to increase the draught by forming grates by laying across the timb a short iron bar, as high up as the dam-stone, by resting upon this bar six or seven other bars or fingers, and by pushing their points against the back stone of the hearth. There is not much iron made during the first 24 hours; most of the ore is transformed into slag, and the iron which comes down gets cold on the bottom stone, where it is retained: the blast should not be urged too fast at first, but increased gradually, in order to avoid the serious evil arising from the cold hearth; if all goes on well the hearth will be free from cold iron or clinkers in a week, the yield of iron will increase, and the burden may be increased, likewise. The average charge of charcoal, which should be dry, coarse, and hard, is about 15 bushels. According to Overman's experience, the most favorable height for a charcoal furnace is 55 or 60 feet; if below this standard they consume too much fuel, if above they are troublesome to work; if it be desired to encrease the capacity of a furnace, he thinks it better to increase the diameter of the boshes, or to curve the vertical section. There is much difference of opinion amongst managers of furnaces on the subject of the proper size for the throat of the furnace; the tendency of narrow throats would seem to be to consume more coal than wide ones, inasmuch as in Pennsylvania and throughout the whole west, where narrow tops are preferred, the consumption of charcoal per ton of iron is from 100 to 150 boshes, while in the State of New York, and further east, where the furnace throats are wider, the consumption is from 120 to 130 boshes. Another subject which demands the strictest attention is the regulation of the blast. A weak soft charcoal will not bear a much greater pressure than from half a pound to five-eighths of a pound to the square inch; strong coarse charcoal will bear from three-quarters of a pound to a pound; and again, it may be laid down as a rule that the larger the throat in proportion to the boshes, the stronger ought to be the blast, and that a narrow top and wide boshes, while they permit a weaker blast, involve the loss of much fuel. In every case a careful roasting of the ores at charcoal furnaces will prove advantageous; this is the surest means of saving coal and blast and of avoiding many annoyances in the working of the furnace.

With regard to hot blast, as applied to charcoal furnaces, Overman remarks, that under some circumstances it might be advantageous, but in others it is decidedly injurious; that it is at least a questionable improvement, and it may be doubted whether the manufacture of bar iron has derived any benefit from it; qualitatively it has not. Hot blast is quite a help to imperfect workmen: it melts refractory ores, and delivers good foundry metal with facility.

English process of iron making.—Mr. Hunt, in his very valuable "Mineral Statistics," gives us the total quantity of pig iron produced in Great Britain in the year 1858:

<table>
<thead>
<tr>
<th>Region</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northumberland</td>
<td>45,312 tons</td>
</tr>
<tr>
<td>Durham</td>
<td>365,184</td>
</tr>
<tr>
<td>Yorkshire, North Riding</td>
<td>189,320</td>
</tr>
<tr>
<td>Do. West Riding</td>
<td>85,956</td>
</tr>
<tr>
<td>Derbyshire</td>
<td>131,577</td>
</tr>
<tr>
<td>Lancashire</td>
<td>2,840</td>
</tr>
<tr>
<td>Cumberland</td>
<td>24,254</td>
</tr>
<tr>
<td>Shropshire</td>
<td>101,046</td>
</tr>
<tr>
<td>North Staffordshire</td>
<td>133,308</td>
</tr>
<tr>
<td>South Staffordshire and Worcestershire</td>
<td>597,809</td>
</tr>
<tr>
<td>Gloucestershire</td>
<td>23,550</td>
</tr>
<tr>
<td>Northamptonshire</td>
<td>9,750</td>
</tr>
<tr>
<td>Wilts and Somerset</td>
<td>2,040</td>
</tr>
<tr>
<td>North Wales</td>
<td>28,150</td>
</tr>
<tr>
<td>South Wales</td>
<td>885,478</td>
</tr>
<tr>
<td>Scotland</td>
<td>925,500</td>
</tr>
</tbody>
</table>

3,156,064 tons.
IRON.

The number of furnaces in blast to furnish this astonishing make are, in England, 332, distributed over 162 iron works; in Wales, 153, distributed over 57 works; and in Scotland, 133, over 32. To supply these furnaces there were raised, 8,040,959 tons of ore, the estimated value of which, at a mean of 11s. per ton, is £4,422,527; that of the pig iron, at a mean money value of £4 a ton, being £13,824,256. Of the ironstone 1,650,000 tons were argillaceous carbonate from the coal measures of Staffordshire; nearly 1,500,000 tons from the coal measures of North and South Wales; and 2,212,250 tons argillaceous carbonate from Scotland. The annual production of pig iron over the whole world was estimated by Mr. Blackwell, in December, 1855, as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Britain</td>
<td>3,000,000</td>
</tr>
<tr>
<td>France</td>
<td>750,000</td>
</tr>
<tr>
<td>United States of America</td>
<td>750,000</td>
</tr>
<tr>
<td>Prussia</td>
<td>300,000</td>
</tr>
<tr>
<td>Austria</td>
<td>250,000</td>
</tr>
<tr>
<td>Belgium</td>
<td>200,000</td>
</tr>
<tr>
<td>Russia</td>
<td>200,000</td>
</tr>
<tr>
<td>Sweden</td>
<td>150,000</td>
</tr>
<tr>
<td>Various German States</td>
<td>100,000</td>
</tr>
<tr>
<td>Other countries</td>
<td>300,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6,000,000</td>
</tr>
</tbody>
</table>

From which it appears that the quantity of iron made annually in this island alone, is nearly, if not quite, as large as the total quantities produced in all other countries. The nature of the ore which forms the staple supply of the English furnaces, (argillaceous carbonate,) and the universal adoption of coke and coal as fuel, have led by necessity to a method of manufacture of iron quite peculiar to this country, and wholly inapplicable to those establishments that are carried on by means of charcoal. We shall proceed to describe the various steps of this manufacture in detail:—and first,

Of the blast furnace.—The blast furnaces at present in use are of various sizes, being from 35 to 60 feet in height, and at the boshes, or widest part, from 12 to 17 feet. The internal form commonly adopted consists essentially of two frustums of cones meeting each other at their bases, at the point where the widest part or the top of the boshes is situated. From this point the furnace gradually contracts both upwards to its mouth, and downwards to the level of the tuyeres below. The hearth, properly speaking, is that part of the furnace only which receives the fluid metal and cinder, as they fall below the level of the tuyeres. It forms a short prolongation from that point of the lower inverted cone. From the boshes upwards the width gradually decreases to the tunnel head, which varies from 7 to 9 feet in diameter, according to the size of the furnace. The hearth is generally a cube, from 2½ to 3 feet square. The air is introduced by one, two, or three small apertures, called tuyeres. When two tuyeres are used, the orifices of their blowpipes are about three inches in diameter, and the pressure of blast is from 2½ to 3 lbs. on the square inch. To prevent the tuyeres from being melted by the intense heat to which they are exposed, a stream of cold water is caused constantly to flow round their nozzles by an arrangement which will be immediately understood by an inspection of fig. 336, which represents a section of a tuyere nozzle thus protected, the cold water entering the casing by the tube a, and the hot water running off by the tube b. The upper part of the furnace above the boshes is called the cone or body. It is formed by an interior lining of fire-brick, about 14 inches in thickness, between which and the exterior masonry is a casing of fine refractory sand compactly rammed in, air holes being left for the escape of aqueous vapor. In the base of the furnace four arches are left, the back and sides are called tuyere houses, the front is called the cinder fall; the bottom of the furnace is formed either of large blocks of coarse sandstone or of large fire-bricks. The materials are charged into the furnace through the tunnel head, which is provided with one or more apertures for the purpose. The general form of a blast furnace is shown in fig. 337, and the following measurements represent the interior structure of two that worked well:—
The form of the blast furnace from the boshes to the throat is exhibited in fig. 337 as a truncated cone, and such was formerly invariably the construction; of late years, however, considerable variations have been introduced. In Scotland the body of the furnace frequently is carried up cylindrical, or nearly so, for a considerable height, terminating with the usual truncated cone to the mouth; in other places a curved line is substituted for a straight one. The form adopted in some furnaces recently erected at Ebbw Vale and Blaina is shown in fig. 338.

The diameter of the throat or filling place is a subject of very great importance to the operations of the furnace. Most iron masters are, we believe, agreed as to the impolicy of the narrow tops formerly adopted; the waste of fuel in such furnaces, where the width of the throat scarcely averaged one-fourth of the diameter of the furnace, was very great, the average yield of coal to the ton of crude iron exceeding 6 tons; by enlarging the throat to one-third, the consumption of coal was reduced to 4 tons, and by continuing the enlargement to one-half it was reduced to 2 tons. Mr. Truran states that on reducing the diameter of the throat of a furnace at Dowlais from 9 feet to 6, the make of pig iron weekly fell off from 27 tons, to an irregular make of from 30 to 70 tons; and that while with the 9-feet throat the consumption of coal was 45 cwt. to the ton of iron, it rose with the 6-feet throat to 70, 80, 90 cwt., the quality of the iron being exceedingly bad. On enlarging the throat to 9½ feet, the make, for a period of 6 months, averaged over 160 tons, with a good yield of coal and other materials. Mr. Truran appears to question the utility of reducing the diameter of the furnace at the top, which was only adopted in the first place from an erroneous impression that the furnace could be filled best through a contracted mouth; but it may be questioned whether this widening of the throat may not be carried too far, so as to disperse the heated gases too rapidly, and whether a diameter much greater than one-half of the largest dimensions of the furnace above the boshes can with utility be adopted. On this subject Mr. Kenyon Blackwell says: "If that part of the blast furnace commencing at the point where it attains its greatest width were continued of the same wide dimensions upwards to its mouth, two objectionable results would ensue: first, the upper part of the furnace would be cooled by the too rapid dispersion of the ascending column of heated gases, and by the entire absence of the reverberating effect of the contracted mouth; and secondly, the materials

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* The width of the hearth differs greatly in the furnaces in different localities. In Scotland it varies from 6 to 8 feet; in the Welsh furnaces from 6 to 8 feet. When coke is used as fuel, Mr. Truran thinks 6 feet a sufficient width for all purposes; but with coal, with full-sized furnaces, 16 to 19 feet across the boshes; he thinks a 7-foot hearth to be more advantageous.

† The diameter of the boshes in some of the Welsh furnaces is as much as from 15 to 19 feet.

‡ The angle with which the boshes rise in different furnaces varies from 50° to 80°. Mr. Truran thinks that when the full smelting power of the furnace is desired, the angle should not be less than 70°, which is about that of the Scotch furnaces.
could not be equally spread from the filling holes over so wide a surface. The diameter of the upper part furnace ought, therefore, to be such as will cause the materials thrown in at the filling holes to distribute themselves equally in their descent over every part of the sectional area of the furnace, and will produce such a reverberation only of heat as shall be sufficient to expel the water and carbonic acid contained in the materials, without consuming any of the carbon of the fuel, which ought to remain intact until it reaches the lower regions of the furnace, where it is vaporized as carbonic oxide, and produces the reactions on which the reduction of the ore depends."

Calcination of the ironstone.—This is effected either in kilns, or in the open air; the object being to separate carbonic acid, water, sulphur, and other substances volatile, at a red heat. The operation is performed most effectually, and probably at the smallest cost, in kilns. The interior shape of the calcining kilns differs in different works, but they may all be reduced to that of the common lime kiln. A coal fire is first lighted at the bottom of the kiln, and the ironstone is placed over and around, until the floor is covered with red hot ore; a fresh layer of ironstone, with about 5 per cent. of coal, is then laid on, to the depth of 8 or 9 inches; and when this is red hot, a second layer is added, and so on gradually till the kiln is filled; by the time this is done, the lowermost layer is cold and fit to draw, so that the working of the kiln is a continuous operation. When the ore is calcined in the open air, a heap mingled with small coal (if necessary) is piled up over a stratum of larger pieces of coal, the heap being 5 or 6 feet high, by 15 or 20 broad. The fire is applied at the windward end, and after it has burnt a certain way, the heap is prolonged at the other extremity, as far as the nature of the ground, or the convenience of work requires. From the impossibility of regulating the draught, and from exposure to the weather, the calcination of ore cannot be so well performed in the open air as in kilns; and as to the relative cost of the two methods, Mr. Truran calculates that the quantity of coal per ton of ore is, in the kiln, one hundredweight of small; and in the open air,
two hundred-weights of small, and a half hundred-weight of large; and that while the
cost of filling the kiln is barely a penny per ton, that of stacking the heaps on the open
air plan, and watching them during the period they are under fire, amounts to fourpence
per ton. Against this must, however, be placed the cost of erecting the kiln, which ac-
cording to the same authority amounts, for a kiln of a capacity equal to 70 tons of
argillaceous ore, which will calcine 140 tons weekly, to £160. The ironstone loses by
calculating from 25 to 30 per cent., of its weight: it has undergone a remarkable change
by the operation; in the raw state, it is a gray or light brown stony-looking substance,
not attracted by the magnet; after calcination it has a dry feel, adheres strongly to the
tongue, is cracked in all directions, is of a light reddish color throughout, and acts pow-
erfully on the magnet. It should be carried to the furnace as soon as possible, or if kept
should be carefully protected from the rain.

Plan.—The only flux that is used in the blast furnace is limestone, either in the state
of carbonate as it comes from the quarry, or calcined in kilns, by which it is deprived of
water and carbonic acid. The lowest bed of the coal formation usually rests on lime-
stone, and in the coal formation itself are found not only the ore and its most appropriate
fuel, but the pebbly grits which afford the blocks of refractory stone necessary for build-
ing those parts of an iron furnace that are required to endure the utmost extremity of heat.
Such an arrangement of lime and charcoal is especially suitable for the materials of the
furnace lined. “Thus many situations in this favored island may be pointed out, in which all the above-mentioned materials
occur almost on the same spot; and when to this is joined the convenience of water
 Carrie, as happens in many places, that man must indeed be of an obtuse understand-
ing and a churlish temper in whom this wise arrangement and prodigy beneficence of
nature fail to produce corresponding feelings.”—Akin.

The composition of the limestone to be used in smelting operations is of considerable
importance; where calcareous ores are used, the presence of siliceous acid in the limestone
is advantageous; if clay ores are the main material from which iron is manufactured, a
magnesian limestone is preferable, but an aluminous limestone should be used where silici-
sious ore predominates. Chemical analysis alone can determine to which class a particu-
lar limestone belongs, as there is often nothing in the external appearance by which a pure
limestone may be distinguished from one containing 10 or 50 per cent. of foreign matter.

Carbonized pit-coal or coke was, till within the last twenty-five years, the sole combust-
ible used in the blast furnace. Coal is coked either in the open air or in kilns. In the
former, as practised in Staffordshire, the coal is distributed in circular heaps about 5
feet in diameter by 4 feet high, and the middle is occupied by a low brick chimney piled with
loose bricks, to open or to leave interstices between them, especially near the ground.
The larger lumps of coal are arranged round this chimney, and the smaller ones towards
the circumference of the mass. When every thing is adjusted a kindling of coals is intro-
duced into the bottom of the brick chimney, and, to render the combustion slow, the
whole is covered with a coat of coal-dress, the chimney being loosely covered with a slab
of any kind. Openings are occasionally made in the crust, and afterwards shut up, to
quicken and retard the ignition at pleasure during its continuance of twenty-four hours.
Whenever the carbonization has reached the proper point for forming good coke the
covering of coal dress is removed, and water is thrown on the heap to extinguish the
combustion—a circumstance deemed useful to the quality of the coke. In this operation,
in Staffordshire coal loses the half of its weight, or two tons of coal produce one of coke.

In order to prepare larger quantities of coke at once, long ridges are often substituted
for circular heaps, the length of which varies with circumstances and the consumption
of coke; they sometimes extend to the length of 200 feet. On erecting one of these
ridges a string is stretched along the coking station, in the direction of which large
pieces of coal are placed slanting against each other, leaving a triangular space between
them, so that a longitudinal channel (ignition passage) is formed through which the string
passes. In arranging the pieces it is necessary to pay attention to the natural strati-
fication of the coals, which should be at right angles to the longitudinal direction of the
ridge. Parallel with the first series of coals is placed a second, and then a third, and so on;
but the pieces constantly diminish in size until the station measures 8 feet on both sides. Upon
this substructure the heap is then made, without particular care in the arrangements, the
largest pieces below and the smallest above, until it has reached a height of about 3 feet.
To facilitate the ignition, stakes are rammed in at distances of 2 feet from each other,
projecting above throughout the whole length of the ridge, which, when subsequently re-
moved, leave vacant spaces for the introduction of burning coal. The ridge, being thus
knifled at more than 100 distinct spots, soon breaks out into active combustion. As soon
as the burner observes the thick smoke and flame cease at any one part, and a coating
of ash making its appearance, he endeavors immediately to stop the progress of the fire
by covering it with powdered coal dust, repeating the operation until the whole ridge is
covered, when it is left two or three days to cool; the covering on the side exposed to the
wind should be thicker, and increased in stormy weather. When the fire is nearly extinguished, which occurs in two or three days, the coke is drawn. This mode of coking is simple, but not very economical. The fire proceeding from the upper part of the ridge in a downward direction, towards the lower and interior parts, converts the coal in the upper strata into coke before that in the interior has acquired the temperature necessary for charring, and is still in want of a supply of air, which can only be furnished from without and must not be excluded by a covering. During the time, therefore, that the inner parts of the heap are being converted into coke, the outer portions are being uselessly, though unavoidably, consumed. See the articles Coal and Coke.

The "blowing in" of a coal blast furnace is an operation which requires much care and experience. A fire of wood is first lighted on the hearth; upon this is placed a quantity of coke, and when the whole is well ignited, the furnace is filled to the throat with regular charges of calcined ore, limestone, and coke, and the blast, which should at first be moderate, is turned on. At the works around Merthyr Tydvil, the first charges generally consist of 5 cwts. of calcined argillaceous ore and 1/4 cwts. limestone, to 4 cwts. of rich coke; this burden is kept on for about 10 days; it is then increased to 6 cwts. of calcined ore and 2 1/2 cwts. of limestone.—(Truran.) The cinders usually make their appearance in about 12 hours after blowing; the metal follows in about 10 hours after, collecting in the hearth to the amount of 3 or 3 1/2 tons in 60 hours after blowing. If all goes on well about 22 tons of metal will be produced in the first week, 28 tons in the second, 55 in the third, and nearly 80 in the fourth; after 10 or 12 weeks the produce will average 110 tons. By forcing the furnace in its infancy, a much greater produce of iron may be obtained, though to the injury of its subsequent working. Mr. Truran relates the following case in point:—A furnace was blown in at the Abercychan works with such volumes of blast and rich burden of materials that a cast of several tons was obtained within 14 hours after applying blast. The first week's blowing produced 200 tons, at which rate it continued for two or three weeks, when it rapidly diminished, falling so low as 19 tons for one week's make. From this deplorable state it was made to produce 26 tons, and, after considerable delay, 100 tons; but with a large increase in the yield of materials over that at the other furnaces. When a furnace is first blown in it should be made to produce gray iron, but the tendency of forcing to produce a white iron with a dark scoriaceous cinder.

The quantity of air thrown into a blast furnace in full work is enormous, exceeding in weight the totals of all the soiled materials used in smelting. A furnace working on foundry iron of a capacity of 275 yards receives 5,390 cubic feet of air per minute, which amounts weekly to 1,665 tons; when working on white iron a larger volume of blast is employed, averaging 7,370 cubic feet per minute, or 2,318 tons per week.

The disorders to which blast furnaces are liable have a tendency to produce white cast iron. The color of the slag or scoria is the surest test of these derangements, as it indicates the quality of the products. If the furnace is yielding an iron proper for casting into moulds, the slag has an uniform vitrifaction and is slightly translucent. When the dose of ore is increased the slag becomes opaque, dull, and of a greenish yellow tint, with blue mottled portions. Lastly, when the furnace is producing white metal, it is more or less black and glossy. The scoria from a coke are much more loaded with lime than those from a charcoal blast furnace. This excess of lime appears adapted to absorb and carry off the sulphur which would otherwise injure the quality of the iron. From numerous analyses we have made of blast furnace cinders we select the following as illustrating their general composition under different conditions of the furnace—

### Analyses of Blast Furnace Cinders. (Dr. Noad.)

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sillen</td>
<td>49.70</td>
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<td>41.12</td>
<td>49.30</td>
<td>49.40</td>
<td>49.55</td>
<td>47.86</td>
</tr>
<tr>
<td>Alumina</td>
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<td>14.12</td>
<td>22.90</td>
<td>12.48</td>
<td>21.98</td>
<td>27.33</td>
<td>20.20</td>
</tr>
<tr>
<td>Lime</td>
<td>39.00</td>
<td>33.35</td>
<td>29.45</td>
<td>26.58</td>
<td>17.56</td>
<td>19.80</td>
<td>16.19</td>
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<tr>
<td>Magnesia</td>
<td>7.16</td>
<td>9.14</td>
<td>1.55</td>
<td>3.20</td>
<td>4.86</td>
<td>2.75</td>
<td>2.79</td>
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<tr>
<td>Protocoxide of magnesio</td>
<td>tracess</td>
<td>tracess</td>
<td>tracess</td>
<td>12.29</td>
<td>1.94</td>
<td>2.00</td>
<td>1.58</td>
</tr>
<tr>
<td>Protocoxide of iron</td>
<td>1.90</td>
<td>2.10</td>
<td>3.30</td>
<td>2.20</td>
<td>3.99</td>
<td>19.12</td>
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<tr>
<td>Fusfibes</td>
<td>1.70</td>
<td>1.14</td>
<td>not determined</td>
<td>1.13</td>
<td>1.25</td>
<td>1.18</td>
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<tr>
<td>Sulphuret of calcium</td>
<td>1.70</td>
<td>3.16</td>
<td>1.60</td>
<td>2.20</td>
<td>1.49</td>
<td>1.45</td>
<td>1.92</td>
</tr>
<tr>
<td>Loss</td>
<td>83.92</td>
<td>83.92</td>
<td>83.92</td>
<td>83.92</td>
<td>83.92</td>
<td>83.92</td>
<td>83.92</td>
</tr>
</tbody>
</table>

I. Mean of four analyses of gray iron cinders from a furnace at Blaina, South Wales. II. Mean of analyses of gray iron cinders from an iron works in Yorkshire. III. Mean of four analyses of gray iron (cold blast) cinders from Pontypool, South Wales. IV. Mean of four analyses of green cinder from a furnace at Ebbw Vale, Monmouthshire, smelting apatite ore. V. Mean of four analyses of blast furnace cinders from Sweden. VI. Mean of four analyses of white iron cinder from a furnace at Gwn Celyn Iron Works, Monmouthshire. VII. Mean of four analyses of white iron cinder from the same works, the furnace "scoriac."
The following table exhibits the "yields" of materials per ton of iron made in various works. During the month ending July 20th, 1857, there were consumed in four furnaces at Ebbw Vale 1,354 tons 14 cwt. of coke; 1,792 tons of coal; 2,440 tons 19 cwt. of calcined mine; 1,818 tons 10 cwt. of red ore; 1,347 tons 6 cwt. of calcined clinders; and 1,226 tons 7 cwt. of burnt lime. The quantity of pig iron made was 2,305 tons 7 cwt.:

Yields of Materials per Ton of Iron.

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
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<th>VIII</th>
<th>IX</th>
</tr>
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<tr>
<td></td>
<td>cwt.</td>
<td>cwt.</td>
<td>cwt.</td>
<td>cwt.</td>
<td>cwt.</td>
<td>cwt.</td>
<td>cwt.</td>
<td>cwt.</td>
<td>cwt.</td>
</tr>
<tr>
<td>Calcined mine</td>
<td>45</td>
<td>25</td>
<td>0</td>
<td>46</td>
<td>33</td>
<td>27</td>
<td>21</td>
<td>37½</td>
<td>49½</td>
</tr>
<tr>
<td>Hematite</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>21</td>
<td>15½</td>
<td>15</td>
</tr>
<tr>
<td>Clinders</td>
<td>0</td>
<td>10</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>11½</td>
<td>11½</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Coal</td>
<td>42</td>
<td>56</td>
<td>34</td>
<td>40</td>
<td>34</td>
<td>34</td>
<td>34</td>
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<td>34</td>
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<tr>
<td>Limestone</td>
<td>17</td>
<td>14</td>
<td>16</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

I. Dowlais foundry iron. II. Dowlais forge iron. III. Dowlais inferior forge iron. IV. Hirwaun foundry iron. V. Dundee, Scotland, foundry iron. VI. Pontypool cold blast foundry iron. VII. Ebbw Vale forge iron. VIII. Owain Colwyn forge iron. IX. Coalbrook Vale foundry iron.

The "cinders" mentioned in the foregoing table are not those from the blast furnace, but are derived from the cast iron during the processes of "refining," "puddling," &c., by which the cast iron is converted into wrought iron. These cinders are very rich in iron, which exists in them principally in the form of silicate of the protoxide. They often occur beautifully crystallized, particularly after they have been calcined—an operation which is always performed on them in well-conducted works, and which has for its object the removal of the sulphur and the peroxidation of a portion of the iron. These cinders, though very rich in iron, are always contaminated to a considerable extent with both sulphur and phosphorus, as might be expected, seeing that they are the results of operations which have for their objects the removal of the foreign matters contained in the pig iron. The tendency of the former is to make the metal what is called "hot short," so that it cannot be worked while hot under the hammer; the tendency of the latter element is to make the iron "cold short," so that it breaks when an attempt is made to bend it when cold. The separation of sulphur is very perfectly effected by the calcination of the cinder, and it is interesting to trace the progress of its gradual elimination. In some parts of the heap (which often contains several thousand tons of cinder) large masses of prismatic crystals of pure sulphur may be found, but usually nearly the entire surface of the heap is covered with a thin layer of sulphate of iron, sometimes crystallized, but generally in various stages of decomposition; lower down in the heap, where the heat is greater, the sulphate of iron disappears, and in its place red oxide of iron, without a trace of sulphur, is found. In calcining a heap of cinders care is required not to allow the heat to rise too high, or immense masses will become melted together, involving the necessity of blasting, which entails much expense. After the heap has been burning for some months, streams of water are directed over the surface, by which much soluble sulphate of iron is removed. Unfortunately, the process of calcination does not remove any of the phosphoric acid, which necessitates a judicious employment of these cinders in the blast furnace. We have repeatedly submitted "forge cinders" to analysis, and give in the following table the average results of our experiments:

Analyses of Forge Cinders. (Dr. Noad.)

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siliice</td>
<td>60</td>
<td>60</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Protosil</td>
<td>60</td>
<td>60</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Peroxide</td>
<td>60</td>
<td>60</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Sulphur</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Manganese</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Alumina</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Lime</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Magnesia</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

I. Tap cinder from refined metal. II. Tap cinder from puddling furnace. III. Cinder from reheating furnace. IV. Mixed cinder from the heap after a few days' burning. V. Cinder squeezed out of the puddling bar during the process of shingling. VI. Specimen from a large heap of thoroughly calcined cinder.

The experiments through which Mr. Nielson's important discovery of the hot blast was introduced into the iron manufacture, were made at the Clyde Iron Works, where the fuel
generally made use of was coke, derived from splint coal; during its conversion into coke, this coal sustained a loss of 55 per cent. During the first six months of the year 1829, when all the cast iron in the Clyde Iron Works was made by means of the cold blast, a single ton of cast iron required for fuel to reduce it 8 tons 14 cwt. of coal, converted into coke. During the first six months of the following year, while the air was heated to near 300° F., 1 ton of cast iron required 5 tons 24 cwt. of coal converted into coke. The saving amounts to 2 tons 18 cwt. per ton of iron, from which must be deducted the coal used in heating the air, which was nearly 8 cwt. This great success induced the Scotch iron masters to try a higher temperature, and to substitute raw coal for coke; and during the first six months of the year 1834, the blast being heated to 600°, 1 ton of cast iron was made with 2 tons 53 cwt. of coal. Add to this 8 cwt. of coal for heating, and we have 2 tons 13 cwt. of coal to make one ton of iron. An extraordinary impetus was given by this discovery to the iron manufacture in Scotland, where, from the peculiar nature of the coal, and from the circumstance that, with a heated blast, Musil's blackband ironstone could be exclusively used, its importance was more highly felt than in England and Wales. According to Mr. Finch's statement, (Scrivenor's "History of the Iron Trade," there were in 1830 only eight works in operation in Scotland, which made in that year 37,700 tons of pig iron; in 1838 there were eleven works, consisting of 41 furnaces, which made 147,500 tons, being an increase in eight years of 110,000 tons per annum; in 1859, there were 50 furnaces in blast, making 318,000 tons; in 1851, 150,000 tons of pig iron were made; and in 1864, with 127 furnaces in blast, the make rose to 890,000 tons. The influence of hot blast has likewise been felt in the anthracite district of South Wales, where that coal is now successfully used, and where several furnaces have in consequence been erected. In short, notwithstanding the opposition with which the introduction of hot blast was met by engineers, as being destructive of the quality of the iron, so great have been the advantages derived from it, that at the present time more than nineteen-twentieths of the entire produce of the kingdom is made in furnaces blown with heated air.

Mr. Truran, in his recent work on the iron manufacture of Great Britain, gives it as his opinion that the effects of hot blast have been greatly exaggerated, and that it is to improvements in the preparation of fuel and ore in the furnaces, in blowing engines, and in the smelting process, far more than to the heating of the blast, that we must refer the great reduction in the yields of coal in recent times; he thinks that the comparatively large produce which has been obtained from the Scotch furnaces, is to be referred to the general use of carbonaceous ore, which melts at a low temperature, and which, from its comparatively freedom from earthy matters, requires but a minimum dose of limestone for fluxing. Against this opinion of an English writer on iron smelting we may place that recorded by an American metallurgist, Mr. Overman, who has written a large and in many respects a valuable treatise on the manufacture of iron, as conducted in America. "The most marked advantages arising from the application of hot blast, casting aside those cases in which cold blast will not work at all, are immense. The amount of fuel saved in anthracite and coke furnaces varies from 30 to 60 per cent. In addition to this, hot blast enables us to obtain nearly twice the quantity of iron within a given time that we should realize by cold blast. These advantages are far more striking with respect to anthracite coal than in relation to coke or to bituminous coal. By using hard charcoal, we can save 20 per cent. of fuel, and augment the product 50 per cent. From soft charcoal we shall derive but little benefit, at least where it is necessary to take the quality of the iron into consideration."

The following tables, embodying the general results of an extended series of experiments on the relative strength and other mechanical properties of cast iron, obtained by the hot and cold blast, are extracted from a report presented to the British Association (1827) by Messrs. Eaton, Hodgkinson, and William Fairbairn.

Of the three columns of numbers, the first represents the strength or other quality in the cold blast iron, the second that in the hot, the third is the ratio of these qualities; the figures included in parentheses indicate the number of experiments from which the results have been deduced.

These results concern nearly the whole of the information afforded by the investigation. From the numbers in the tables, it will be seen that in Buffery iron No. 1, cold blast somewhat surpasses hot blast in all the following particulars:—1, direct tensile strength; 2, compressive strength; 3, transverse strength; 4, power to resist impact; 5, modulus of elasticity or stiffness; 6, specific gravity; while the only numerical advantage possessed by the hot blast metal is that it bends a little more than the cold before it breaks. In No. 2 the advantages of the rival kinds are more nearly balanced, still rather in favor of the cold blast. No. 3 hot blast Carron iron resists both tension and compression better than cold blast of the same denomination; and No. 6 hot blast from the Devon works in Scotland is remarkably strong, while No. 6 cold blast is comparatively weak, notwithstanding its high specific gravity. On the whole it would appear from the experiments, that while the irons of Nos. 1 and 6 have been somewhat deteriorated in quality by the hot blast, those of No. 3 have been benefited by its mollifying powers; while those of No. 2 have been but very slightly
affected; and from the evidence brought forward, it is rendered highly probable that the introduction of a heated blast, while it has, perhaps, to a certain extent, injured the softer irons, has improved those of a harder nature; and considering the small deterioration that the irons of the quality No. 2 have sustained, and the apparent benefit of those of No. 3, together with the saving effected by the heated blast, there seems good reason for the process becoming so general as it has done.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength in lbs. per square inch</td>
<td>16,653 (2)</td>
<td>13,265 (3)</td>
<td>1000 : 909</td>
</tr>
<tr>
<td>Compressive strength in lbs. per inch, from castings torn asunder</td>
<td>106,375 (3)</td>
<td>106,340 (3)</td>
<td>1000 : 1020</td>
</tr>
<tr>
<td>Dito, from prisms of various forms</td>
<td>100,003 (4)</td>
<td>100,038 (2)</td>
<td>1000 : 991</td>
</tr>
<tr>
<td>Dito, from cylinders</td>
<td>125,463 (2)</td>
<td>121,085 (3)</td>
<td>1000 : 970</td>
</tr>
<tr>
<td>Transverse strength from all experiments</td>
<td>- (9)</td>
<td>- (9)</td>
<td>1000 : 1000</td>
</tr>
<tr>
<td>Power to resist impact</td>
<td>- (9)</td>
<td>- (9)</td>
<td>1000 : 1000</td>
</tr>
<tr>
<td>Transverse strength of bars one inch square in lbs.</td>
<td>475 (3)</td>
<td>463 (3)</td>
<td>1000 : 978</td>
</tr>
<tr>
<td>Ultimate deflection of do. in inches</td>
<td>1.66</td>
<td>1.805</td>
<td>1000 : 1015</td>
</tr>
<tr>
<td>Modulus of elasticity in lbs. per square inch</td>
<td>11,157,000 (2)</td>
<td>10,058,000 (2)</td>
<td>1000 : 903</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>7.966</td>
<td>7.949</td>
<td>1000 : 997</td>
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</thead>
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<tr>
<td>Tensile strength</td>
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<td>- (5)</td>
<td>1000 : 1417</td>
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<tr>
<td>Compressive strength</td>
<td>- (5)</td>
<td>- (5)</td>
<td>1000 : 1417</td>
</tr>
<tr>
<td>Transverse do. from experiments generally</td>
<td>- (5)</td>
<td>- (5)</td>
<td>1000 : 1417</td>
</tr>
<tr>
<td>Power to resist impact</td>
<td>- (4)</td>
<td>- (4)</td>
<td>1000 : 2738</td>
</tr>
<tr>
<td>Transverse strength of bars one inch square</td>
<td>448 (2)</td>
<td>337 (3)</td>
<td>1000 : 1199</td>
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<tr>
<td>Ultimate deflection do.</td>
<td>1.69</td>
<td>1.60</td>
<td>1000 : 1200</td>
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<tr>
<td>Modulus of elasticity</td>
<td>22,907,200 (2)</td>
<td>22,473,000 (2)</td>
<td>1000 : 973</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>7.765 (4)</td>
<td>7.729 (2)</td>
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<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>15,255 (3)</td>
<td>16,037 (2)</td>
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</tr>
<tr>
<td>Compressive strength</td>
<td>74,770 (4)</td>
<td>62,739 (4)</td>
<td>1000 : 902</td>
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<tr>
<td>Specific gravity</td>
<td>5.954 (4)</td>
<td>6.065 (4)</td>
<td>1000 : 1002</td>
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</table>

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
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<td>14,290 (2)</td>
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<td>1000 : 1250</td>
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<tr>
<td>Compressive strength</td>
<td>115,349 (4)</td>
<td>109,440 (2)</td>
<td>1000 : 1135</td>
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<tr>
<td>Specific gravity</td>
<td>7.103 (1)</td>
<td>7.056 (1)</td>
<td>1000 : 989</td>
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</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>17,460 (1)</td>
<td>18,334 (1)</td>
<td>1000 : 760</td>
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<tr>
<td>Compressive strength</td>
<td>93,566 (4)</td>
<td>86,097 (4)</td>
<td>1000 : 923</td>
</tr>
<tr>
<td>Transverse strength</td>
<td>- (5)</td>
<td>- (5)</td>
<td>1000 : 974</td>
</tr>
<tr>
<td>Power to resist impact</td>
<td>- (5)</td>
<td>- (5)</td>
<td>1000 : 974</td>
</tr>
<tr>
<td>Transverse strength of bars one inch square</td>
<td>436 (3)</td>
<td>436 (3)</td>
<td>1000 : 973</td>
</tr>
<tr>
<td>Ultimate deflection do.</td>
<td>1.55</td>
<td>1.64</td>
<td>1000 : 1015</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>13,857,250 (2)</td>
<td>13,799,500 (2)</td>
<td>1000 : 966</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>7.079</td>
<td>6.955</td>
<td>1000 : 965</td>
</tr>
</tbody>
</table>

The following general summary of results, as derived from the experiments of Messrs. Hodgkinson and Fairbairn on the transverse strength of hot and cold blast iron exhibits at one view the ultimatum of the whole investigation.

<table>
<thead>
<tr>
<th>Ratio of Strength</th>
<th>Ratio of Powers to sustain Impact—Cold Blast being represented by 1000.</th>
</tr>
</thead>
<tbody>
<tr>
<td>These irons are from Mr. Hodgkinson's experiments:</td>
<td></td>
</tr>
<tr>
<td>Carron iron, No. 2</td>
<td>1000 : 290:9</td>
</tr>
<tr>
<td>Devon iron, No. 2</td>
<td>1000 : 1416:9</td>
</tr>
<tr>
<td>Buffery iron, No. 1</td>
<td>1000 : 330:7</td>
</tr>
<tr>
<td>These irons are from Mr. Fairbairn's experiments:</td>
<td></td>
</tr>
<tr>
<td>Cowd Talon iron, No. 2</td>
<td>1000 : 1007</td>
</tr>
<tr>
<td>Cowd Talon dito, No. 3</td>
<td>1000 : 922</td>
</tr>
<tr>
<td>Elsicar and Milton, dito</td>
<td>1000 : 818</td>
</tr>
<tr>
<td>Carron dito, No. 3</td>
<td>1000 : 1181</td>
</tr>
<tr>
<td>Muirkirk, No. 1</td>
<td>1000 : 927</td>
</tr>
<tr>
<td>Mean</td>
<td>1000 : 1094:8</td>
</tr>
</tbody>
</table>

Dr. Thompson's chemical examination of several samples of hot and cold blast iron is appended to this report. According to the experiments of this distinguished chemist, iron smelted by hot blast contains a greater proportion of iron, and a smaller proportion of silicon, carbon, and aluminum, than when smelted by cold air. The mean specific gravity of 8 speci-
mens of Scotch cold blast iron No. 1, was 6:7034; the mean of 5 specimens of hot blast from the Carron and Clyde iron works was 7:0628, so that the density of cold blast iron is less than that of hot. The mean of 6 analyses of cold blast iron No. 1, gave 3 3/4 atoms of iron, 1 atom of carbon, silicon, and aluminum; the proportion of these three constituents being very nearly 4 atoms of carbon, 1 atom of silicon, and 1 atom of aluminum; consequently Scotch cold blast iron consists of 20 atoms of iron, (with a little manganese,) 4 atoms of carbon, 1 atom of silicon, and 1 atom of aluminum. The mean of 5 analyses of hot blast iron No. 1, gave 6 1/2 atoms of iron and manganese to 1 atom of carbon, silicon, and aluminum, from which it would appear that cast iron smelted with a heat blast is purer than when the blast is cold. This, however, is not the case, as the numerous analyses of both varieties that have been made during the last few years concur in proving. Hot blast gray iron smelted with mineral coal contains a much higher percentage of silicon than the same variety of cast iron smelted from the same ores by cold blast; in other respects, provided the process of reduction is complete, i.e. when little or no iron passes off with the slag, there is very little chemically difference between the two varieties, as will be seen in the following table, which contains the results of a series of analyses of hot and cold blast iron, which we have lately had occasion to make, under circumstances peculiarly favorable for instituting the comparison, the furnaces working with the same ores, and making the same class of iron, viz. good No. 3 gray pig.

**Analyses of Cast Iron No. 3, smelted by Hot Blast. (Dr. Noad.)**

<table>
<thead>
<tr>
<th></th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
<th>IV.</th>
<th>V.</th>
<th>VI.</th>
<th>VII.</th>
<th>VIII.</th>
<th>Mean,</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon</td>
<td>2.500</td>
<td>3.140</td>
<td>3.320</td>
<td>3.440</td>
<td>3.900</td>
<td>3.390</td>
<td>3.790</td>
<td>2.920</td>
<td>3.000</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.045</td>
<td>0.090</td>
<td>0.070</td>
<td>0.069</td>
<td>0.072</td>
<td>0.066</td>
<td>0.072</td>
<td>0.064</td>
<td>0.069</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.018</td>
<td>0.022</td>
<td>0.006</td>
<td>0.002</td>
<td>0.022</td>
<td>0.002</td>
<td>0.022</td>
<td>0.004</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Metallic iron per cent. 93.12

**Analyses of Cast Iron No. 3, smelted by Cold Blast. (Dr. Noad.)**

<table>
<thead>
<tr>
<th></th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
<th>IV.</th>
<th>V.</th>
<th>VI.</th>
<th>VII.</th>
<th>VIII.</th>
<th>Mean,</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon</td>
<td>1.000</td>
<td>1.400</td>
<td>1.629</td>
<td>0.926</td>
<td>1.372</td>
<td>1.456</td>
<td>1.406</td>
<td>1.400</td>
<td>1.295</td>
</tr>
<tr>
<td>Graphite</td>
<td>2.570</td>
<td>3.184</td>
<td>3.270</td>
<td>3.149</td>
<td>3.033</td>
<td>3.274</td>
<td>2.924</td>
<td>3.157</td>
<td>3.251</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.021</td>
<td>0.037</td>
<td>0.040</td>
<td>0.002</td>
<td>0.022</td>
<td>0.037</td>
<td>0.032</td>
<td>0.054</td>
<td>0.039</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.018</td>
<td>0.014</td>
<td>0.007</td>
<td>0.002</td>
<td>0.022</td>
<td>0.002</td>
<td>0.022</td>
<td>0.004</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Metallic iron per cent. 93.0

The true reason of the frequent inferiority of hot blast iron has been correctly given by Mr. Blackwell. Furnaces blown with heated air exert greater reductive power than those in which a cold blast is used. This has led, since the introduction of hot blast, to the extensive use in iron smelting of refractory ores not formerly smelted, a large part of which have been ores of a class calculated to produce inferior iron, and it is to the use of ores of this nature, far more than from any deterioration in quality, arising from a heated blast, that this inferiority of hot blast iron is to be ascribed.

**Utilization of the waste gases given off from the furnace hood.**—The agent in the blast furnace by which the oxide of iron is reduced, is carbonic oxide, the presence of which, therefore, in great excess is indispensable to the operation of the furnace. The flames rising from the tunnel head, which make a blast furnace at night such an imposing object, are occasioned principally by the combustion of this gas, on coming into contact with the oxygen of the atmosphere; the attention of practical men was first called to the enormous waste of heat which this useless flame entailed by Messrs. Dunsen and Playfair, and the application of the gas to a useful purpose may be ranked next to that of the heated blast, as the most important of the recent improvements in the iron manufacture. The gases evolved from iron furnaces where coal is used as the fuel, contain the following constituents, viz.: nitrogen, ammonia, carbonic acid, carbonic oxide, light carbonated hydrogen, olefiant gas, carbonated hydrogen of unknown composition, hydrogen, sulphurised hydrogen, and aqueous vapor. The nature of the combustible gas stands in a relation so intimate to the changes suffered by the materials put into the furnace, that its different composition in the various regions of the furnace indicates the changes suffered by the materials introduced as they descend in their way to the entrance of the blast. Now as the examination of this column of air in its various heights in the furnace must be the key to the questions upon which the theory and practice of the manufacture of iron depends, it was of the first importance to subject it to a rigid examination; this examination was made by the above-named eminent chemists, and subsequently by Ebelmen. We shall return to a consideration of the results they obtained presently, confining our attention at present to the composition of the gases at the mouth of the furnace, and to the methods which have been adopted to utilize them.
In order to arrive at a knowledge of the composition of these gases, M. Bunsen first studied minutely the phenomena which would ensue were the furnace filled with fuel only; by a careful distillation of a known weight of coal, and analyzing the products, he obtained results embodied in the subjoined table:

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<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Carbon</td>
<td>68.925</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Tar</td>
<td>12.230</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Water</td>
<td>7.569</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Light carburetted hydrogen</td>
<td>7.021</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Carbonic oxide</td>
<td>1.135</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>1.073</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Condensed hydrocarbon and olefiant gas</td>
<td>0.753</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Sulphuretted hydrogen</td>
<td>0.349</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.455</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.211</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.085</td>
<td>100.000</td>
<td>100.000</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th></th>
<th>100.000</th>
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Now, in the furnace, the oxygen introduced by the blast is consumed in the immediate vicinity of the tuyère, being there converted into carbonic oxide, and the coal loses all its gaseous products of distillation much above the point at which its combustion commences, near in fact, the top of the furnace; the fuel with which the blast comes into contact is, therefore, coke, and upon calculating the amount of carbonic oxide produced by the combustion of 68.925 per cent. of carbon, and the nitrogen of the air expended in the combustion, we get as the composition by volume of the gases escaping from a furnace filled with Gusforth coal the following:

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<thead>
<tr>
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<tbody>
<tr>
<td>Nitrogen</td>
<td>62.423</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Carbonic oxide</td>
<td>33.163</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Light carburetted hydrogen</td>
<td>2.527</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>0.139</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Condensed hydrocarbon</td>
<td>0.151</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Sulphuretted hydrogen</td>
<td>0.091</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>1.451</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.070</td>
<td>100.000</td>
<td>100.000</td>
</tr>
</tbody>
</table>

With this preliminary information, Bunsen proceeded to calculate the modification of the gaseous mixture occasioned by the introduction into the furnace of iron ore and limestone. The materials used for the production of 140 lbs. of pig-iron were:—

420 lbs. calcined iron ore; 396 lbs. coal; 170 lbs. limestone. From 100 parts of the coal, 67.228 parts of coke were obtained; but from this must be deducted 2.68 ashes, and 1.18 carbon entering into combination with the iron; which leaves as the quantity of carbon actually burnt into carbonic oxide before the tuyère 63.368; part of this carbonic oxide undergoes oxidation into carbonic acid at the expense of the oxygen in the oxide of iron which it reduces, a further quantity of carbonic acid is derived from the limestone; so that the gases returned to the mouth of the furnace by the combustion of the 67.228 parts of coke, the reduction of the corresponding quantity of ore, and the decomposition of limestone, consist of—

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</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>282.860</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>59.482</td>
<td>100.000</td>
<td>100.000</td>
</tr>
<tr>
<td>Carbonic oxide</td>
<td>121.906</td>
<td>100.000</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Add to this the products of the distillation of the coal, and we get the following as the percentage compositions by weight and measure of the gases issuing from the mouth of the furnace.

<table>
<thead>
<tr>
<th></th>
<th>By weight.</th>
<th>By volume.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>60.007</td>
<td>59.339</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>12.765</td>
<td>8.270</td>
</tr>
<tr>
<td>Carbonic oxide</td>
<td>26.066</td>
<td>26.846</td>
</tr>
<tr>
<td>Light carburetted hydrogen</td>
<td>1.397</td>
<td>2.536</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.978</td>
<td>1.125</td>
</tr>
<tr>
<td>Condensed hydrocarbon</td>
<td>0.163</td>
<td>0.112</td>
</tr>
<tr>
<td>Sulphuretted hydrogen</td>
<td>0.065</td>
<td>0.045</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.054</td>
<td>0.058</td>
</tr>
</tbody>
</table>

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<th>100.000</th>
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IRON.

The calculations of the quantity of heat capable of being realized in the furnace by the combustion of the furnace gases are founded on the data on the heat of combustion given in the posthumous papers of Dulong, according to which—

1 kilogramme or 15,444 grains of

| Carbon burning to CO, heats 15,444 grains of water to | 14°9°C |
| Carbonic oxide | 20°71° |
| Hydrogen | 2°502° |
| Light carburetted hydrogen | 34°706° |
| Oleflant gas | 13°409° |
| Sulphuretted hydrogen | 12°822° |
| Ammonia | 44°70° |

Using these numbers it is found that by the combustion of 100 of the furnace gases there are generated from the

| 59°559 nitrogen | 0000 |
| 12°765 carbonic acid | 0000 |
| 26°056 carbonic oxide | 65°067 |
| 1°307 carburetted hydrogen | 18°826 |
| 0°608 hydrogen | 2°704 |
| 0°108 oleflant gas | 1°851 |
| 0°033 sulphuretted hydrogen | 2°83 |
| 0°034 ammonia | 2°08 |

85874—

units of heat generated, the unit being understood to mean the amount of heat necessary to raise 1 kilogramme = 29.04 lbs. = 15,444 grains of water from 0° centigrade, to 1° cent. The amount of heat realized in the furnace is limited to that produced by the expenditure of the oxygen, corresponding to 59°559 nitrogen in the production of carbonic oxide; this amount to 20,001 units; hence follows the remarkable conclusion, that in the furnace which was the subject of experiment, not less than 81.54 per cent. of the fuel is lost in the form of combustible matter still fit for use, and that only 18.46 per cent. of the whole fuel is realized in carrying out the processes in the furnace.

The temperature which should be produced by the flame of the furnace gases when burnt with air, is found by dividing the units of heat, viz. 85874 arising from the combustion of 1 kilogramme of the gases by the number resulting when the quantity of the products of combustion is multiplied by their specific heat (1.5358 x 0°2696); we thus get the number 3083° F.; but this is below the truth, inasmuch as there is an ascension of combustible gases at the mouth of the furnace, arising from the decomposition of the liquid products of the distillation of the coal in its passage over the red-hot fuel. Making proper correction for this, and using numbers derived from actual experiments, Messrs. Bunsen and Playfair calculated the temperature of the gases when generated under favorable conditions at 3214° F., and even this may be increased to 3582° F., a temperature far above that of cast iron, by the using a blast sufficiently heated. In utilizing these waste gases, care must be taken not to remove them from the furnace till they really are waste, that is, until they have done their work in the furnace; it is obvious that no combustible matter could be removed from the lower regions of the furnace without seriously deranging the operations essential to the reduction and smelting of the ore. In order to remove the gases effectually, and without injury to the working of the furnace, and in such a state as will permit their combustion to be effected with most advantage, the height of the furnace must be raised, the full width of the mouth being retained, and the gases must be withdrawn sufficiently far below the mouth for them to be obtained dry, and also beneath the point where they begin to enter into combustion from contact with the atmospheric air.

Various modes of collecting the gases have been tried; the best seems to be that adopted at Ebbw Vale, Sirhowy, and Cwm Celyn. A funnel-shaped casting, equal in its largest diameter, to the throat of the furnace, projects into the interior a depth of 4 or 5 feet; the orifice at the bottom from 3 to 5 feet in diameter is closed by a conical casting, the apex upwards, from which a chain proceeds to a lever having a counterpoise at the other end. (See fig. 535.) The materials are filled into the funnel-shaped receptacle, and are charged into the furnace with a uniform distribution, by lowering the cone by means of suitable machinery, which again returns it to its place when emptied. The circular space around the funnel, inside the furnace, forms a chamber for the reception of the gases, from which they are conveyed by brick tunnels or iron piping to the place of combustion. The whole arrangement will be clearly understood by an inspection of the accompanying plans, figs. 340, 341, 342, 343, 344, kindly furnished to the writer by the proprietor of the Cwm Celyn and Blaina Iron Works.
Fig. 342 shows the plan of extracting the gases which is adopted at the Brymbo Iron Works, near Wrexham, the same being the patent of C. E. Darby.

It consists of a large pipe or tube inserted into the middle of the top part of the furnace, which descends a short distance down into the materials, and is carried over the top of the side of the furnace in the form of a syphon, a continuation of which pipe is taken to the boilers, or hot-air stoves, where the gas is burned in the usual way. The principal advantage claimed by this method is that it puts no check on the free escape of the gases, by which the driving of the furnace is impeded, and the quality of the iron deteriorated. The patent estimates the saving of fuel with two furnaces making 240 tons of iron per week, by applying the gas to the blast engine boilers and hot-air stoves, at £1,200 a year. Thus:—Consumption of fuel at engine and stoves equal to 7 cwt., of good coal per ton of iron, made at 3½ per cwt., is 20. 9½d., say 2s. per ton on 12,450 tons, or £1,248.

The causes of derangement in the working of blast furnaces when the gases are drawn off to be utilized elsewhere, have been diligently studied by Mr. George Parry, of Ebbw Vale; and he has kindly furnished us with the following resumé of his observations, for insertion in this article.

The manner in which the waste gases were formerly collected, was by sinking an iron tube, 7 feet deep, into the throat of the furnace, the diameter of the tube being about 5 feet less than that of the throat, thus leaving an annular space of 18 inches between the walls of the furnace and the sides of the tube. From this space the gases were allowed to pass off by the pressure within the furnace, through a pipe which penetrated the ring and walls. When the tube was kept full of minerals, about ⅔ or ⅔ only of the gas escaped into the open air, the rest passing into the annular chamber; and when this state of things was continued, those troublesome adhesions of masses of semifused materials, above and around the boshes, technically termed "seafolds," occurred, with the usual accompaniments of black cinder and inferior iron. It is evident that when the tube was kept full of minerals, the contents acted as a loose stopper to the current of hot gases forced up by pressure from beneath, and diverted them towards the annular space where there was no such resistance, thus leaving the minerals in the central parts of the furnace insufficiently supplied with the upward current, and consequently with heat; the minerals, on the other hand, surrounding this cold central cone, were supplied with more than their usual quantity of heat, as was evidenced by the burning of tuyères, and by the destruction of the brickwork in their neighborhood. In this state of things the ores in the external portions of the furnace would
become reduced and converted into gray metal; while those in the central portions would, according to the degree of deviation of the ascending current of heated gases from them, descend to the point of fusion either thoroughly deoxidized, and slightly carbonized, or possibly with a portion still in the state of oxide, and mixing there with the properly reduced ores, enter into fusion with them, producing a mixture of irons which must necessarily prove of inferior quality, and a black cinder from the unreduced oxides. When the iron tube in the throat of the furnace was kept only partially filled with minerals, much more gas escaped into the open air, as might have been expected, and consequently more traversed the central parts of the furnace; and it was always observed that when that mode of filling was adopted, the furnace worked much better: but then the object, viz. that of economizing the gases, was not attained. Differently formed furnaces were found to be disturbed in different degrees by this system of drawing off the gases: the old conical narrow topped furnaces were affected very much less than the improved modern domed top furnace of large capacity, from which all attempts to take off any useful portion of the gases proved absolute ruin. It might be argued, that as the same quantity of blast and fuel was used as heretofore, the ascending current of heated gases ought to produce the same deoxidizing and carbonizing effect on the superincumbent mass, whatever direction they might take in making their escape at the upper region of the furnace; for if the central part should not have been sufficiently acted upon, the external annulus would have more than its usual
share of chemical influences. But when it is considered that iron is only capable of taking up a certain quantity of carbon, and no more, it follows that after having received this dose, its further exposure in the external parts of the furnace where the hated gases abound can do nothing towards supplying the deficiency of carbon in the metal reduced in the central part. From these considerations, it became evident that no system of drawing off the gases around the sides, whether by the insertion of an iron tube into the throat, or by lat-

Vot. III.—41
would be to take the gases from a chamber above the surface of the minerals, thus equalizing the pressure on the whole sectional area of the mouth, and thereby allowing an equally free flow for the ascending current up the middle, as well as up the sides of the furnace. By this method the whole of the waste gases would become utilized, instead of a portion only, and the furnace would be restored to its original state, insurmountable as the direction of the flow of heated gases would not be interfered with by unequal resistance. To form this chamber, the furnace must be covered in, and fed through a hopper, a plan long adopted at the Cocker Park Iron Works, with the supposed advantage of scattering the minerals around the sides of the furnace, and preventing their accumulating in the centre; a conical charger of this description, but fixed in the throat of the blast furnace, was in use at the Cyfartha Works, more than half a century ago, the minerals being thrown by baskets to the centre of the cone, and allowed to roll down to the sides of the furnace, thus giving a cup form to the surface of the minerals, the larger lumps of course rolling to the centre, and affording a freer passage in that direction for the upward current. It was not, however, until January, 1851, that a trial was made at the Ebhaw Vale Works, of an apparatus of this description for collecting the gases. It was then supplied to one of the old forms of conical furnace with a narrow top, and the trial proved eminently successful, the furnace producing any quantity of iron required according to the burden, as usual. Several other furnaces were similarly furnished in and around the neighborhood, and it was now thought that the principle of taking off the gases from a chamber above the surface of the minerals, together with the conical mode of charging, were the only indispensable conditions to success for all furnaces; and some even which were originally built too narrow at the mouth, were actually improved by the new method of charging, which did not allow of the surfaces of the minerals rising higher than about 6 feet from the top; thus giving to the furnace a diminished height, and as a consequence of its conical shape, a wider mouth. Further experience, however, demonstrated the fallacy of this general conclusion.

A large domed furnace was furnished with the same kind of charging apparatus which proved so successful in former instances, but to the astonishment of all it turned out a complete failure, the same derangements occurring as in the former cases, where a portion of the gases only was collected, by sucking a tube into the throat. Now this furnace could not be filled to within 6 or 7 feet of the top, and at that depth the diameter was 13 ft. 6 in., owing to the sharp sweep of the dome; the actual working furnace was therefore 37 feet high, instead of 44 feet, with a mouth 13 ft. 6 in., instead of 8 ft; and as the minerals cannot lie so close against the smooth sides of the walls as they do locked in each other in the more central region of the furnace, a much freer discharge of the gases up the sides must take place; and on boring a hole through the side of the furnace, in the neighborhood of the boses, it was found that 2 feet in, the coke and other minerals were at a white heat, but a little further on towards the centre, lumps of black blazing coal were found, with tuftron which had not even attained a red heat. The charging apparatus was now raised with the furnace 5 feet, and the minerals drawn up an inclined plane to the charge-cup, thus enabling it to be kept full to within a short distance of the old mouth, after which the furnace worked as usual. That diminished height was not the cause of the bad working of the furnace was afterwards proved, the furnace having been blown out for repairs, and lined with brickwork, giving it that form and proportion deemed necessary, from the experience gained; the height being now only 37 feet, instead of 44, and the diameter of the mouth 7 ft. 6 in., or one-half of that at the boses. The same charging apparatus which failed before, mounted 5 feet above the mouth, was used, and the furnace has now been working uninterruptedly for 5 years, turning out as much as 160 tons of gray pig iron per week, or when burdened for white iron, 200 tons; economizing the whole of its gas, and as much under the control of the manager as any furnace, either closed top or open top, can reasonably be expected to be. It is clear, therefore, that the covering of the top has nothing whatever to do with the action of a furnace kept full to the mouth, and having the proper form and proportions from that point downwards. The mouth must be understood to be that part of the furnace which represents the mean height of the surface of the minerals, and not the top of the masonry, and the question arises, what proportion should that bear in diameter to the boses or widest part, and what the latter should be with reference to height in order to secure a maximum economical effect on the quality of the iron made, and on the yield of fuel. This state of perfection can exist only when the isothermal lines in the furnace are parallel to the horizon; the temperature of the minerals at any given height above the tuyères being the same through the whole horizontal sectional area at that height, and consequently arriving at the zone of fusion in an equally prepared state. If the mouth of the furnace be too wide, the heated gases have a greater tendency to pass up the sides than through the centre, thus destroying the horizontality of the lines of equal temperature, and giving them a curved form with the convex side downwards; hence errors of different temperatures, and of various stages of preparation, will occupy any given horizontal sectional area of the furnace; these descending together, and mixing in the zone of fusion, will produce evils in proportion to the extent of the deflection of the curves from a hori-
IRON. 643

gontal line. On the contrary, if the mouth of the furnace be too narrow in proportion to the other parts, we may expect an undue portion of the gases to pass up the centre, leaving the minerals around the sides comparatively unacted upon. It is easy to see that evils of the same kind as before must exist here, the isothermal lines becoming now convex downwards, instead of concave, giving as before, through any horizontal section of the furnace, oes at various temperatures, and at different degrees of deoxidation or carbonation, according to the depth which they may have attained in the furnace. There are several instances of furnaces originally built with too narrow tops, being greatly improved by widening them; this may conveniently be done by feeding them through a conical charger, which has the advantage of the minerals being thus discharged close to the edge, the larger lumps having a tendency to roll over towards the centre, leaving the smaller at the ring walls, to check the upward current in that direction.

The above considerations will materially assist in furnishing an answer to the oft repeated and very important question, "What form and proportion should a blast furnace have to produce the best results in quality of iron, and in economy of fuel, whether worked on the open top principle, or enclosed for the purpose of utilizing the waste gases?" Experience has proved that when the mouth of the furnace is one-half the diameter of the widest part, good work is obtained, and that any deviation from that proportion, if in excess, has been productive of great derangement in its action. The height of the furnace should also bear a certain proportion to the greatest diameter, in order to secure a uniform flow of the ascending current through all its parts; for if the widest part bear too great a relation to the height, the bosses must necessarily be of a low angle, and consequently the minerals around the sides near their top be at too great a distance out of the direct line of passage of the ascending current, and consequently remain only partially prepared for fusion.

The proportions recommended by Mr. Parry, and which have been practically tested most satisfactorily in several instances, are as shown in fig. 316. The mouth b b' one-half the diameter of the widest part c c, and this should not be at a less depth than its own diameter. The sides of the furnace to this depth should be formed slightly dome-fashioned, for the purpose of giving to that region a larger capacity than would be obtained by a conical form. The radius of the curve should be at right angles to the axis of the furnace, and formed by a prolongation of the line representing the greatest diameter. When the radius is set at a great angle with this line, which is often done to give greater capacity to the domed part, the distortion produced by the sharpness of the curve may leave a segment of the minerals unacted upon by the gases in their passage to the mouth, and entail greater evils than would be compensated for by increased capacity. The curve is continued below the widest part of the furnace till it meets the top of the bosses d d, the angle of which should not be less than 70°, and start from the point of the tuyères f. The depth also from the widest part to the tuyères should not be less than its own diameter p as half the diameter of the tuyeres. These proportions give a blast furnace, of any determinate height fixed upon, the largest possible capacity it is capable of receiving, while remaining free from any distortion of form, likely to give a place for minerals to lie out of the way of the action of the upward gaseous current; when the height exceeds the proportion to its greatest diameter indicated in the figure, an unnecessary sacrifice in its capacity is the only loss entailed. The height above the mouth must be regulated by the kind of hopper used for charging, where it is intended to carry off the gases.

Doubtless when the true principle of collecting these gases without injury to the blast furnace becomes more generally known, attention will be directed to the easiest and most convenient mode of introducing the minerals. The conical charger has only one disadvantage, that namely of allowing a great waste of gas during the charging; probably some kind of revolving hopper may be contrived to remedy this defect. It is of course assumed that
the furnace is supplied with a proper quantity of blast, and of a density proportional to the diameter across the tuyères, so as to maintain a vigorous combustion of the fuel to the very centre of the hearth, the top of which is indicated by the letters e, e, unless for this is attained, a cold cone of minerals will remain in the centre, and produce derangements which no degree of perfection in the form of the furnace in the higher region can remove.

Theory of the blast furnace.—Analyses of the gases from a furnace at Alfreton in Derbyshire, at various depths below the surface, gave to Messrs. Bunsen, Bunsen and Playfair the results embodied in the subjoined table. The furnace was supplied with 80 changes in the course of 24 hours, each charge consisting of 390 lbs. of coal, 420 lbs. of calcined ironstone, and 170 lbs. of limestone, the product being 140 lbs. of pig iron. The gases were collected through a system of tubes of malleable iron, 1 inch in diameter, and were received in glass tubes, 4 inches long, and of an inch in diameter. The well-known skill of M. Bunsen as a gas analyst is a guarantee of the accuracy of the determinations.

Composition of the Gases taken from different depths in the Furnace.

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>H</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>55-85</td>
<td>54-77</td>
<td>52-25</td>
<td>50-95</td>
<td>50-49</td>
<td>60-46</td>
<td>58-25</td>
<td>56-75</td>
<td>56-60</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>7-77</td>
<td>9-42</td>
<td>9-24</td>
<td>9-09</td>
<td>8-79</td>
<td>9-12</td>
<td>10-48</td>
<td>10-49</td>
<td>10-01</td>
</tr>
<tr>
<td>Light carburized hydrogen</td>
<td>3-75</td>
<td>8-23</td>
<td>4-52</td>
<td>4-64</td>
<td>4-81</td>
<td>1-91</td>
<td>1-94</td>
<td>3-93</td>
<td>0-60</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>6-73</td>
<td>6-49</td>
<td>6-79</td>
<td>12-79</td>
<td>7-02</td>
<td>4-63</td>
<td>1-42</td>
<td>0-00</td>
<td>1-64</td>
</tr>
<tr>
<td>Olefiant gas</td>
<td>0-60</td>
<td>0-10</td>
<td>0-20</td>
<td>1-95</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
</tr>
<tr>
<td>Cyanogen</td>
<td>0-20</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
<td>0-90</td>
</tr>
</tbody>
</table>

From these analyses it appears:—
1. That at a depth of 34 feet from the top, within 2 feet 9 inches of the tuyère, the gas was entirely free from carbonic acid, but contained an appreciable quantity of cyanogen.
2. That the nitrogen is at a minimum at 14 feet.
3. That carburized hydrogen is found so low as 24 feet, indicating that, at that depth, coal must be undergoing the process of coking.
4. That hydrogen and olefiant gases are at a maximum at 14 feet.
5. That the proportions between the carbonic acid and carbonic oxide are irregular, which is probably to be explained by the fact that water is decomposed as its vapor passes through the layers of hot coal.

The average composition of the gases evolved from the materials used in the blast furnace is somewhere between the two following numbers:—

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>H</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>60-907</td>
<td>60-907</td>
<td>60-907</td>
<td>60-907</td>
<td>60-907</td>
<td>60-907</td>
<td>60-907</td>
<td>60-907</td>
<td>60-907</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>8-370</td>
<td>8-370</td>
<td>8-370</td>
<td>8-370</td>
<td>8-370</td>
<td>8-370</td>
<td>8-370</td>
<td>8-370</td>
<td>8-370</td>
</tr>
<tr>
<td>Light carburized hydrogen</td>
<td>2-596</td>
<td>2-596</td>
<td>2-596</td>
<td>2-596</td>
<td>2-596</td>
<td>2-596</td>
<td>2-596</td>
<td>2-596</td>
<td>2-596</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>1-126</td>
<td>1-126</td>
<td>1-126</td>
<td>1-126</td>
<td>1-126</td>
<td>1-126</td>
<td>1-126</td>
<td>1-126</td>
<td>1-126</td>
</tr>
<tr>
<td>Olefiant gas</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
</tr>
<tr>
<td>Olefiant gas</td>
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<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
<td>0-712</td>
</tr>
</tbody>
</table>

The proportion of nitrogen to oxygen as an average deduced from these analyses is 79.2 to 27. The product of the combustion of coal gives the same proportions as those existing in atmospheric air, viz.: 79.2 : 20.08. The excess of oxygen must therefore depend upon the carbonic acid of the limestone, and the oxygen of the ore given to carbon during the process of reduction. Now, as at a depth of 24 feet the gas collected contained 27'6 and 26'5 oxygen to 79'2 nitrogen, it is held that at this depth the gas must already have accumulated all the oxygen of the ore, and the carbonic acid of the limestone; and the conclusion is drawn that, in hot blast furnaces fed with coal, the reduction of the iron and the expulsion of the carbonic acid from the limestone take place in the boshes of the furnace. The exact region of the furnace in which the melting of the iron and the formation of slag are affected is not exactly defined, but it is assumed that the point of fusion is at the top of the hearth. The region of reduction in a furnace smelting with coal must be much lower than when the fuel is coke or charcoal, because a large portion of the body of the furnace must be taken up in the process of coking, and the temperature is thereby so depressed, that it is sufficient neither for the reduction of the ore, nor for the expulsion of carbonic acid from the limestone.

The mean general results obtained by M. Ebelmen from a charcoal furnace at Clerval are given below. The methods of analysis adopted by this chemist were altogether different.
IRON.

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from those employed by Messrs. Bunsen and Playfair. For details we refer to his memoir in the *Annales des Mines*, vol. xix. p. 89, 1853.

<table>
<thead>
<tr>
<th>No. of analysis</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV.</th>
<th>V.</th>
<th>VI.</th>
<th>VII.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth below mouth</td>
<td>3 ft. 9 in.</td>
<td>3 ft. 8 in.</td>
<td>9 ft. 9 in.</td>
<td>9 ft. 9 in.</td>
<td>10 ft. 6 in.</td>
<td>19 ft. 6 in.</td>
<td>27 feet.</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbonic oxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carburated hydrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Oxygen, per 100 nitrogen</td>
<td>42.5</td>
<td>49.6</td>
<td>22.7</td>
<td>22.7</td>
<td>28.5</td>
<td>28.2</td>
<td>30.7</td>
</tr>
<tr>
<td>Carbon vapor, per 100 nitrogen</td>
<td>32.8</td>
<td>31.7</td>
<td>29.6</td>
<td>29.6</td>
<td>28.5</td>
<td>28.5</td>
<td>35.9</td>
</tr>
</tbody>
</table>

I. Gas taken a short time after the introduction of the charge: II. the same taken a quarter of an hour after charging: III. gas collected through a cast-iron tube four inches in diameter; it rushed out with a noise and gave a sheet of flame, carrying with it particles of charcoal and dust: IV. gas collected by boring the masonry; it rushed out violently, burning with a blue-colored flame: V. the same taken an hour after: VI. gas collected by boring the masonry at the back of the furnace about 3/4 feet above the tuyère; it burnt with a white flame, giving off fumes of oxide of zinc; it was collected through porcelain tubes: VII. gas collected through gun-barrels lined with porcelain; it was evolved with sufficient force to project scoriae and even cast iron.

The furnace was working with cold blast under a pressure of 44 inches of mercury. The charges had the following composition:—Charcoal, 253 lbs.; minerals, (various,) 597 lbs.; limestone, 254 lbs. Thirty-two charges were driven in twenty-four hours; the furnace was stopped after every twenty charges; the produce being 3,579 lbs. of black cast iron; the daily yield being about 0,175 lbs.

The experiments show that while the carbonic acid progressively diminishes downwards, the carbonic oxide progressively increases, the former altogether disappearing at a depth of 27 feet. On examining the numbers representing the oxygen and carbon referred to 100 nitrogen, it is seen that they diminish progressively to a depth of 19 feet; the oxygen combined varying from 23.5 to 25.2. The proportion of carbon in the same zone rises from 28.5 to 32.8; a result brought about as much by the carbonic acid disengaged from the minerals as from the gaseous products of the distillation of the charcoal. It is seen that the reduction of the mineral is already considerably advanced at the depth of 19 1/4 feet; and this, so to speak, without any consumption of the distillation of the charcoal. It is seen that the reduction of the mineral is already considerably advanced at the depth of 19 1/4 feet; and this, so to speak, without any consumption of the distillation of the charcoal.

The results obtained by M. Ebelmen from a coke furnace at Serang were as under:

<table>
<thead>
<tr>
<th>No. of experiment</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV.</th>
<th>V.</th>
<th>VI.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>1 foot</td>
<td>1 foot</td>
<td>4 feet</td>
<td>9 feet</td>
<td>10 feet</td>
<td>19 feet</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>11.29</td>
<td>12.12</td>
<td>9.83</td>
<td>9.54</td>
<td>8.88</td>
<td>1.94</td>
</tr>
<tr>
<td>Carbonic oxide</td>
<td>25.61</td>
<td>25.93</td>
<td>25.00</td>
<td>33.88</td>
<td>33.52</td>
<td>33.25</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>2.71</td>
<td>3.04</td>
<td>0.97</td>
<td>0.69</td>
<td>1.72</td>
<td>2.48</td>
</tr>
<tr>
<td>Carburated hydrogen</td>
<td>20.30</td>
<td>26.00</td>
<td>1.43</td>
<td>3.93</td>
<td>0.29</td>
<td>0.25</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>57.06</td>
<td>56.62</td>
<td>59.84</td>
<td>52.46</td>
<td>61.61</td>
<td>61.15</td>
</tr>
<tr>
<td>Totals</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Oxygen, per 100 nitrogen</td>
<td>43.9</td>
<td>45.0</td>
<td>49.0</td>
<td>29.6</td>
<td>28.5</td>
<td>30.6</td>
</tr>
<tr>
<td>Carbon vapor, per 100 nitrogen</td>
<td>35.2</td>
<td>35.7</td>
<td>33.0</td>
<td>29.4</td>
<td>28.5</td>
<td>30.0</td>
</tr>
</tbody>
</table>

I. Gas obtained by plunging an iron tube, three centimetres in diameter, about one foot into the furnace: II. the same; the gas burnt spontaneously: IV. two consecutive analyses of the same gas: V. the gas was collected by an iron tube: VI. gas collected by piercing the masonry two feet above the tuyères; the gas was accompanied by fumes of cyanide of potassium, but no cyanogen could be detected.

The furnace was 50 feet high; the air was supplied through two tuyères, and was heated to 212°; it was driven at the rate of 26,940 gallons per minute under a pressure of 3 lbs. of mercury. The charges were composed of: unroasted minerals, 1,454 lbs.; forge clinders, 1,454 lbs.; limestone, 948 lbs.; coke, 1,755 lbs. The metal was run every twelve hours, and 17,500 lbs. of white crystalline cast iron obtained, which was run on thin plates and
taken directly to the puddling furnace. The yield of the mineral was 42 per cent., and the consumption of coke 1,900 per 1,000 of cast iron, rising from 1,800 to 2,000 per 1,000 of iron when the furnace was working for foundry iron.

The analyses show a rapid diminution of.carbonic acid, and indicate that in the upper regions of the furnace an energetic reduction of ores takes place by the oxide of carbon under the influence of the high temperature of the ascending gases. Between one and nine feet the limestone is calcined. The reduction of the ore takes place at this region by the conversion of carbonic oxide into carbonic acid, without change of volume, and without consumption of carbon. The increase in the hydrogen is too small to induce a supposition that aqueous vapor in decomposing can dissolve any notable quantity of carbon. The gases collected at a depth of about 12 feet represent about the mean composition of the gaseous mixture; from that point to a depth of 45 feet, two-thirds of the total height of the furnace, the gases do not sensibly vary, and are composed almost entirely of carbonic oxide and nitrogen. At 12 feet the oxygen is to the nitrogen as 29:9 to 109; in atmospheric air it is as 26:3 to 100. The difference, 3:6, represents the oxygen arising from the reduction of the silicates of iron constituting the forge cinders, which thus is seen to take place between the tuyère and a depth of 12 feet. These silicates are well known to be decomposed with difficulty, but they are reduced at the high temperature prevailing in that zone of the furnace, and their reduction gives rise to a corresponding quantity of carbonic oxide, to a consumption of fuel, and to a considerable absorption of latent heat. The other minerals are reduced higher up in the furnace, and this is common to all coke furnaces, being due to the high temperature of the ascending gases, a temperature much higher than exists in charcoal furnaces, a far larger quantity of combustible being consumed. Hence it is that forge cinders can be successfully used in coke furnaces; while in charcoal furnaces the introduction of small quantities only alters the working of the furnace, makes the iron white, and very rapidly the walls of the furnace in consequence of the imperfect reduction.

From his eudiometric experiments on the gases from coke and charcoal furnaces, Ebelmen deduces the following conclusions:—

1. That the amount of carburetted hydrogen is too small to exercise any influence over the chemical phenomena of the furnace.
2. That the atmospheric air thrown into the furnace by the tuyère produces successively carbonic acid and carbonic oxide, at a small distance from the opening. The first of these reactions gives rise to an exceedingly high temperature; the second, on the contrary, causes a great absorption of latent heat, and a corresponding lowering of the temperature of the gaseous current. The limits of the zone of fusion bear relation to the space in which the transformation of carbonic acid into carbonic oxide takes place.
3. That the ascending current consisting of carbonic oxide and nitrogen, with a little hydrogen, produces in ascending two distinct effects: it communicates one part of its sensible heat to the materials of the descending column; it becomes charged with all the volatile products disengaged at different heights, and it reduces the oxide of iron to the metallic state. Sometimes this transformation gives rise to an increase in the quantity of carbonic oxide; sometimes, on the contrary, it effects the conversion of carbonic oxide into carbonic acid without change of volume, and without combustion of fuel. Wherever the reduction of oxide of iron takes place with the production of carbonic oxide, there is a consumption of fuel, and an absorption of latent heat. It is essential, therefore, to the good working of the furnace that the minerals should arrive completely reduced to that part where the temperature is sufficiently elevated for the conversion of carbonic acid into carbonic oxide by contact with carbon; this condition is nearly always realized when the oxide of iron is in a free state in the mineral. The reduction of the oxide when in combination with silica requires, on the other hand, a high temperature, and it can only take place in that zone of the furnace where the carbonic acid has completely disappeared.
4. That the zone where carbonic oxide exists alone is much more extended in coke than in charcoal furnaces, and is nearer the mouth in the former than in the latter: it falls lower, however, in the cylinder with hot blast, the quantity of heat remaining the same.
5. That the volatile gaseous matters from the distillation of the charcoal pass into the escape gases, and exert no influence on the reduction of the minerals.

The mutual relation of the carbonic acid and carbonic oxide, which is observable in the analyses of Ebelmen, is not found in those of Bunsen and Playfair; this is attributed by Ebelmen to the circumstance that the latter chemists collected their gases through narrow iron tubes, which, becoming intensely heated and partially choked by the fragments of ore and fuel introduced by the rapid stream of gas, so modified the composition of the gases, that the analysis, however carefully conducted, could not represent accurately their real composition. Ebelmen collected his gases through wide tubes, and from the lower parts of the furnace, by piercing the solid masonry. It is obvious, however, that none but very general conclusions can be drawn from the analysis of the furnace gases, in whatever way they may be collected, for their composition cannot be the same under all circumstances; the nature of the fuel, the pressure of the blast, and (as Mr. Parry's experiments prove) the
shape of the furnace itself, must each exert an influence in modifying the circumstances which affect their composition. Although, therefore, it is impossible to fix the precise region of the furnace where the reduction of the oxide of iron begins to take place, that is, to define precisely the limits of the "zone of reduction," we may in considering the theory of the production of crude iron divide the furnace into four zones:—1. The zone of reduction; 2. The zone of carburation; 3. The zone of fusion; 4. The zone of oxidation. The zone of reduction will vary in extent, according as the furnace is working with coal or with coke; with hot blast or with cold. The zone of carburation commences just below the top of the boshes, the reduced metal in a soft and malleable state here acquires carbon, its rapid sinking being retarded by the contraction which the sides of the furnace begin to undergo from this point downwards. As the carbonized metal passes through the zone of fusion it melts, together with the earthy matters which serve to protect it from the oxidizing effect of the fourth zone, that of oxidation, through which it passes in its passage through the crucible. If the temperature of the zones of fusion and oxidation be not much higher than the melting point of specular iron, the metal in the crucible will be white, with little or no graphite; and if the iron remain sufficiently long in the zone of carburation to take up the maximum quantity of carbon, it will be bright iron. The reduction of silicon appears to take place at about the melting temperature of specular iron: it exists, therefore, in small quantity in white iron, and in greatest abundance in the gray iron smelted from refractory ores, which require a high temperature.

The proportion of carbonic acid in the gases obtained from different heights in a furnace has been studied by MM. E. Montefiore Levi and Dr. Emil Schmidt (Zeitschrift des Danischen Ingenieurveroes, 1882). They found that the zone from which this gas emerges is of very limited extent, for although it is not met with at a height of 8 feet from the tuyère, it exists at 9 feet to the extent of 4.78 per cent., above which point it diminishes up to 15 feet, where it is 0. From this point it again increases, amounting at a height of 30 feet to 5.5 per cent. It then gradually diminishes, until, at a point from 37 to 39 feet above the tuyère, it amounts to only 1.9 or 1.91 per cent.; after which it goes on increasing with rapidity and regularity up to the furnace mouth. The carbonic acid existing in the furnace gases between 15 and 30 feet is referred by these chemists to the decomposition of the limestone used as a flux; and its gradual diminution above this point indicates a reaction of considerable importance, that namely of the carbonic acid upon the ignited coke carbon being taken up and carbonic oxide formed. Now, the quantity of carbon taken up by 275 parts of carbonic acid to convert it into carbonic oxide, amounts to 15 parts, and as in the furnace experimented with, 30,000 kilogrammes of limestone, containing about 8,000 kilogrammes of carbonic acid, were consumed every 24 hours, a loss of fuel equivalent to 2,178 kilogrammes of carbon was daily occasioned by the conversion of this carbonic acid into carbonic oxide and this may be considered equivalent to 2,500 kilogrammes of coke with 11 per cent. of ash. The heat absorbed by the conversion of the carbonic acid of the limestone into a gaseous state is found by calculation, taking the specific heat of carbonic acid at 0.22, and the heating power of coke at 6,900, to be equivalent to that developed by the combustion of 322 kilogrammes of coke. Now it was demonstrated by Dulong that the quantity of heat disengaged in the conversion of carbon into carbonic oxide is much less than that disengaged in the conversion of carbonic oxide into carbonic acid, although the same quantity of oxygen is required in both cases. The conversion of carbonic acid into carbonic oxide, by passing over ignited carbon, is essentially a twofold action; a combination of carbon with oxygen, and a decomposition of carbonic acid into carbonic oxide and oxygen: the former is accompanied by development, the latter by absorption of heat; the latter preponderates to such an extent as to indicate a loss of temperature equivalent to the heat developed by the combustion of 1,609 kilogrammes of coke.

These considerations led the authors to employ burnt lime in working blast furnaces, and to obviate the loss of heat: the results were not at first satisfactory, the management of the furnace being very difficult, and the slags black and pasty; but subsequently the working was regular and good, and the saving of coke and the increase of production are stated to have been very evident; moreover, the raw iron was of better quality, and all the interior parts of the furnace, especially the tappan stone, remained in a much better state of preservation than when limestone was used.

Varieties and chemical constitution of cast iron.—In commerce there are four principal varieties of cast iron, known respectively as Nos. 1, 2, 3, and 4, or dark gray, bright gray, mottled, and white; these terms, although convenient, do not, however, indicate the intrinsic value of the iron thus denominated, as the variable qualities of ore, fuel, and limestone may exercise such an influence on the resulting crude iron, as to render a low denomination of one manufacturer of greater commercial value than a higher denomination of other makers. The general characters of the four varieties are these:—No. 1. Color, dark gray, in large rounded grains, obtained commonly near the commencement of the casting, when the furnace is in good working order, and when an excess of carbon is present; in flowing it appears pesty, and throws out blue scullitions. It exhibits a surface where crystalline
IRON.

Vegetations develop themselves rapidly in very fine branches; it congeals or fixes very slowly; its surface, when cold, is smooth, concave, and often charged with plumbago; it has but a moderate tenacity, is tender under the file, and susceptible of a dull polish. When melted over again, it passes into No. 2, and forms the best castings. No. 2, color bright gray, of small-grained structure, and interspersed only with small graphite laminae; possesses great tenacity, is easily filed, turned, and bored; may even be hammered to a certain extent; does not readily crack from change of temperature. No. 3 is a mixture of white and gray iron. On strongly mottled iron, little stars and spots of gray iron are found, interspersed in bright or flowery iron; weakly mottled iron exhibits white specks on a gray ground. In streaked iron, gray iron is found above and below, and bright iron in the middle, with strong demarcations. No. 4. White iron varies from tin white to grayish white; it is very brittle, cracking easily, even by change of temperature; it is extremely hard, sometimes even more so than hardened steel, so that it will resist the strongest file, and scratches glass easily. Fracture sometimes laminar, sometimes lamino-radiating, sometimes finely splintered, sometimes dense and conchoidal. As the fracture changes from laminar to conchoidal, the color likewise varies from white to grayish. Mean specific gravity, 7.5. Expands less than gray cast iron when heated, cannot be welded, because it becomes pasty at the very lowest welding heat. When heated to the melting point it does not suddenly pass into the fused state like gray pig iron, but is converted before fusing into a soft pasty mass. In this variety of pig iron the whole of the carbon is united to the iron; it is never used for casting, but always for conversion into malleable iron. The bright iron obtained from spathic iron ore contains the largest proportion of carbon, (5.5 per cent. according to Karsten.) A white iron is always the result of a derangement in the working of the furnace, though it by no means follows that when the iron is white the furnace must necessarily be in a disordered state; the presence of manganese, for example, has a tendency to make white cast iron; but the quality may be excellent. The white iron resulting from derangement flows imperfectly, and darts out in casting abundance of white scintillations; it fixe very quickly, and on cooling exhibits on its surface irregular asperities, which make it extremely rough; it is exceedingly hard, though it is easily broken, the fracture being radiated and lamellar; the bar iron it affords is of inferior description. This kind of iron is always produced when the furnace is carrying a heavy burden of forge cinders containing sulphur and phosphorus. There are thus two distinct kinds of white cast iron:—1st. That obtained from ores containing a large proportion of manganese crystallizing in large plates; this variety is highly prized for making steel. 2d. That resulting from a heavy mineral burden, or from a general derangement of the furnace, or from the rapid chilling of fused gray iron crystallizing in small plates; both are hard and brittle, the first more so than the last. Cast iron, which by slow cooling is gray, becomes white when it is cooled rapidly; on the other hand, when white iron is melted and allowed to cool very gradually, a portion of the carbon crystallizes out as graphite, and gray cast iron is produced.

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>German</td>
<td>a.</td>
<td>0.085</td>
<td>0.085</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
<td>0.027</td>
<td>0.000</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>b.</td>
<td>0.082</td>
<td>0.082</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
<td>0.027</td>
<td>0.000</td>
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</tr>
<tr>
<td></td>
<td>c.</td>
<td>0.085</td>
<td>0.085</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
<td>0.027</td>
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<td>0.067</td>
</tr>
<tr>
<td>French</td>
<td>a.</td>
<td>0.085</td>
<td>0.085</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
<td>0.027</td>
<td>0.000</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>b.</td>
<td>0.085</td>
<td>0.085</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
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<tr>
<td>American</td>
<td>a.</td>
<td>0.086</td>
<td>0.086</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
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<tr>
<td></td>
<td>b.</td>
<td>0.086</td>
<td>0.086</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
<td>0.027</td>
<td>0.000</td>
<td>0.067</td>
</tr>
<tr>
<td>Silesian</td>
<td>a.</td>
<td>0.086</td>
<td>0.086</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
<td>0.027</td>
<td>0.000</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>b.</td>
<td>0.086</td>
<td>0.086</td>
<td>0.012</td>
<td>0.079</td>
<td>0.005</td>
<td>0.027</td>
<td>0.000</td>
<td>0.067</td>
</tr>
</tbody>
</table>

* Very gray pig, from Looebach in the Hartz, cold blast; b, Mottled iron, from the royal works in the Hartz, cold blast; c, Normal gray pig, from the same works, hot blast; d, Gray charcoal pig, cold blast; e, White pig, from Firmy, very short and brittle; f, American gray pig, charcoal; g, American mottled iron; h, American charcoal, white iron; i, Silesian white charcoal, iron, very crystalline; j, the same, but less crystalline; k, Gray Scotch coke pig, from the Calder iron works; l, Scotch coke, No. 4 pig iron; m, Glocowick: No. 4 pig; n, Coulbrookdale Lithmoor best first foundry iron; o, Gray pig iron from Dudley, Staffordshire; p, Ordinary, white iron, very crystalline iron pig, smeared from manganiferous ore; q, The same; r, The same; s, Ordinary white pig.
In some iron works six varieties of pig iron are recognized, which may be classified thus:—1. Foundry iron, large crystals; 2. Second foundry iron, large and small crystals mixed; 3. Dark gray, all small crystals; 4. Bright gray; 5. Mottled; 6. White, verging on mottled.

The preceding table exhibits the composition of some different varieties of Continental, English, and American crude irons. The methods of determining the various elements which nearly always accompany cast iron, are given at the end of this article.

Besides the substances enumerated in the above table, other metals, such as copper, arsenic, chromium, titanium, cobalt, zinc, tin, aluminium, and the metals of the alkalies and alkaline earths, are occasionally found in crude iron, but very rarely in quantities that can at all affect the qualities of the product. The elements, the quantitative estimation of which has been given in the above analyses, do, however, materially modify the physical qualities of cast iron. We shall, therefore, offer a few observations on each.

1st. Carbon.—Iron can take up any quantity of carbon up to a little over 5 per cent., at which point it becomes saturated; the compound thus formed is the white crystalline pig or specular iron (i) (r) (s) (t); when absolutely pure its composition is 94.58% iron and 5.12% carbon; it is a tetra-carburet, FeC₄. The most highly carburetted iron which Paraday and Stodart could produce, consisted of iron 92.26%, carbon 5.94%. There seems no reason for admiring, as some metallurgists have done, the existence of a polycarburet of iron containing 18.3% per cent. of carbon, inasmuch as iron containing under 6 per cent. appears to be completely saturated. The specific gravity of pure tetra-carburet of iron is 7.06; it is the most fusible of all the carbures of iron, its melting point being 1,600° Centigrade; it is brittle and silver white, and crystallizes in oblique parallelepipeds, which are frequently tabular. According to Guilt the carburet of iron existing in gray pig is the octo-carburet, FeC₈, the crystals of which belong to the regular or cubic system, but almost always appear in gray iron in the form of confused octohedral groups. The specific gravity of pure octo-carburet of iron, according to the same authority is 7.15, and its composition 97.33% iron and 2.67% carbon; its color is iron gray, its hardness is inferior, and its fusibility less than that of specular iron; the groups of crystals often found in cavities in large castings are composed of this peculiar carburet. Guilt very ingeniously endeavors to show that in gray pig-iron the carbon of the octo-carburet is partially replaced by silicon, sulphur, and phosphorus; and the iron by manganese and other metals. In like manner the carbon of the tetra-carburet may be partially replaced by silicon, phosphorus, or sulphur, the eliminated carbon appearing in the form of graphite: the same decomposition is effected by heat, and specular iron, if exposed to a temperature considerably above its fusing point, becomes gray; if cooled slowly, the graphite separates in large flakes, if rapidly, in minute particles. Some metallurgists suppose that in gray cast iron, a portion only of the iron is chemically united with carbon, the rest of the metal being dissolved in the carburetted compound in the form of malleable iron: we incline however to the opinion of Guilt, that the whole mass of the iron is in a state of combination with the electronegative constituents, such as carbon, sulphur, phosphorus, and silicon. Thus in the white pig-iron of heavy burden, the there is a deficiency of carbon, that element being replaced by sulphur and phosphorus.

Karsten gives as the mean of several analyses, 3.5865 per cent. as the quantity of carbon in cast-Iron smelted with charcoal from spathic ore. He states, that iron containing as little as 2.3 per cent. of carbon still retains the properties of cast-iron, particularly the faculty of separating graphite when allowed to cool slowly. With 2 per cent. of carbon iron is not forgeable, and scarcely so if it contain only 1.9 per cent. With this quantity of carbon it is steel, though not of the weldable kind, (cast steel;) even with so small a proportion of carbon as 1.75 per cent. it is weldable only in a slight degree; the latter property increases as the hardness of the iron decreases. An amount of iron 1.4 to 1.5 per cent. of carbon in iron denotes the maximum of both hardness and strength. Iron containing 0.5 per cent. of carbon is a very soft steel, and forms the boundary between the steel (i.e. iron which may yet be hardened) and malleable or bar iron. These limits lie perceptibly higher if the iron be pure; and lower if it contain silicon, sulphur, and phosphorus.

The composition of the various carbides of iron, according to Berthier, is as under:—

<table>
<thead>
<tr>
<th></th>
<th>FeC₂</th>
<th>FeC₃</th>
<th>FeC</th>
<th>FeC₄</th>
<th>FeC₅</th>
<th>FeC₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>0.000</td>
<td>0.090</td>
<td>0.519</td>
<td>0.899</td>
<td>0.947</td>
<td>0.9643</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.400</td>
<td>0.310</td>
<td>0.183</td>
<td>0.101</td>
<td>0.053</td>
<td>0.0637</td>
</tr>
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</table>

In the blast furnace, the reduced iron may take up carbon in two different ways:—1. By immediate contact with the incandescent fuel; and 2. By taking carbon from carbonic oxide; thus Fe + 2CO = FeC + CO₂. That iron decomposes carbonic oxide is considered by Le Play and Laurent, to be proved by the following experiment: pure oxide of iron and charcoal were heated in two separate porcelain boats, placed in a glass tube; the air in the tube furnished oxygen to the carbon; carbonic oxide was formed, which was converted
into carbonic acid, at the expense of the oxygen of the oxide of iron; the carbonic acid was again transformed into carbonic oxide, by taking up a fresh quantity of carbon, which was again converted into carbonic acid by taking oxygen from the oxide of iron, and this went on until the whole of the oxide of iron was reduced, the metallic iron then decomposed carbonic oxide, producing carbonic acid and carbide of iron; and this went on till a certain quantity of carbon had combined with the iron, when the action ceased. If the charcoal be very strongly ignited previous to the experiment, the carbonization of the iron does not take place, neither does pure carbonic oxide carbonize iron when passed over the metal at a red heat; the effect in the experiment above described may therefore be due to the carburetted hydrogen evolved from the charcoal. Iron begins to take up carbon when heated only to the softening point, the carbon gradually penetrates the metal, converting it first into steel and then into cast-iron; conversely melted cast-iron gives up carbon to soft iron, which it converts into steel. When white iron (FeC) is heated with acids, nearly the whole of the carbon is eliminated in combination with hydrogen. Gray iron only gives up to hydrogen the carbon which was chemically combined with the iron, the uncombined carbon or graphite remains unacted upon; the dark spot produced upon gray iron by a drop of nitric acid arises from this separation of graphite.

Phosphorus.—In very few specimens of crude iron is this element wholly absent; when it exists in small quantities only, it is said rather to improve the iron for castings, as it imparts to the metal the property of fusing tranquilly; in a larger proportion it weakens the iron. In like manner a very small quantity of phosphorus hardens bar iron without materially influencing the other properties, but when it exceeds 0·5 per cent, it renders the bar brittle, cold short, as it is termed. According to Schaffauchel, both cast-iron and steel are improved by phosphorus and by arsenic; he found the latter in the celebrated Dannebrog iron, and in the Lowmoor iron, and the former in the equally famous Russian (CCND) iron.

Sulphur.—This element imparts to crude iron the property of becoming viscid, and of solidifying quickly with cavities and air-bubbles. It is not certain to what extent, or if at all, the presence of minute proportions of sulphur reduces either the tenacity or the toughness of cast-iron of given quality in other respects. It is stated in the Report of the Commission of Inquiry, as to the manufacture of ordnance on the continent, on the authority of Schür and Mitscherlich, that in certain Swedish works pyrites is thrown into the furnace with the other constituents of the charge, to produce the fine gray mottled iron required for gun founding, and it is added that the effect may be analogous to that of the oxidizing flame in a reverberatory furnace. It is certain that sulphur possesses the property of concentrating carbon in iron: and as mottled iron is a mixture of white and gray iron, it is not difficult to see how the addition of pyrites may determine the formation of this variety of cast-iron in a furnace, which without it would produce gray iron only; but it is scarcely credible that any intelligent founder would resort to such a method of making iron for casting cannon, in which the highest possible degree of tenacity is required. The fine gray mottled iron, which from its tenacity is known to be best fitted for large castings, is said to be prepared without difficulty, by charging the furnace partly with roasted and partly with raw ore, and so regulating the blast that the yield shall be regular, and the slag nearly colorless; these two ores, having different degrees of fusibility, are reduced after different periods in the furnace, and hence afford one of them gray, and the other white iron, the result being, provided the minerals are properly proportioned, a mottled iron, harder and more tenacious than gray iron, obtained by mixing or by smelting in the cupola. It is desirable that the temperature of the furnace should be kept as low as possible, the production of dark gray graphitic iron resulting always from intensity of heat.

When sulphur is melted with iron containing the largest amount of chemically combined carbon, sulphuret of iron is formed on the surface; underneath a layer of graphite, and beneath that, a layer of iron with the maximum of carbon: and when gray iron containing 3·51 per cent. of graphite is melted with sulphur, white iron, containing iron 94·03, combined carbon 4·93, and no graphite, is formed. The tendency of sulphurous ores to produce white metal in their treatment in the blast furnace, has long been known; it was supposed that this was occasioned by the too great fusibility which the sulphur gave to the cast iron, but ores containing large proportions of phosphoric acid will produce very gray iron, notwithstanding their fusibility, so that this explanation does not serve; the experiments above described point to the true reason. The sulphur present in the ore (if as sulphuric acid reduced in the furnace) enters into combination with the iron, displacing a corresponding proportion of carbon, which becomes concentrated in the remainder of the metal, forming white iron. To guard against this, and in order to obtain a metal which shall contain a minimum amount of sulphur, the slags should contain the maximum amount of lime, M. Berthier having shown that this earth decomposes sulphuret of iron at a high temperature, in the presence of carbon. M. Janoyer states, that the proportion of lime and silica in the slag may be as 14 to 6; it is doubtful whether such a highly basic cinder would be
sufficiently fusible. Direct experiments, however, have shown that the amount of sulphur in cast-iron diminishes in proportion as the amount of lime in the slag increases. A still better flux is oxide of manganese, and it is found that when the manganiferous spathose ore constitutes part of the burden of the furnace, sulphur almost entirely disappears from the crude iron. M. Janoyer believes that he has proved experimentally, that the whitening of cast-iron smelted from sulphurous ores, is due, in part at least, to the subtraction of a portion of its carbon, and its volatilization in the form of sulphuret of carbon, by which the temperature of the furnace is lowered; but his experiments on this point require confirmation.

The presence of a very small quantity of sulphur acts very injuriously upon bar iron, so small a proportion as 0.045 rendering the metal "hot short," that is, incapable of being worked at a red heat under the hammer. If the quantity of sulphur in the crude iron exceeds 0.4 per cent., it is scarcely possible to manufacture it into good wrought iron.

**Silicon.**—Like carbon, this element enters into combination with iron in all proportions up to as high as 8 per cent. The largest quantity found by Karaton in pig-iron was 8.46 per cent., but in the above table a specimen of cast-iron containing 4.8 per cent. and we have lately found it in a sample of Nova Scotia iron as high as 3.5 per cent. Generally speaking, grey cast-iron contains more silicon than white, and the greater the quantity of graphite in the crude iron the larger the amount of silicon, because the higher the temperature of the furnace; but this again will depend materially on the quality of the coal, from the ash of which the silicon is probably principally derived. A clean strong coal yielding a small percentage of ash furnishes a cast-iron with less silicon than an inferior coal, the mineral burden being the same. Pig-iron smelted with hot blast contains more silicon than when the blast is cold, because of the higher temperature which prevails in the fusion zone of the furnace. Some analyses illustrating this fact have been already given. According to the experiments of MM. Janoyer and Gauthier the amount of silicon in hot blast cast-iron may be greatly influenced by varying the proportion of limestone in the furnace. Pig-iron obtained with a charge yielding a cinder in which the lime and alumina were to the silica as 7 to 10, had little strength, breaks readily, and analysis showed that it contained 3 per cent. of silicon. By increasing the amount of lime in the charge, so as to obtain a cinder in which the bases were to the silica as 8 to 10, and at the same time employing a blast of the highest attainable temperature, the iron produced had a much greater strength. When the proportion of bases to silica in the cinder was as 20 is to 19, the iron contained only an inappreciable amount of silicon, and the strength was increased in the proportion of 65 to 45. When the maximum quantity of lime was used the consumption of fuel was on the average increased to the extent of 6 per cent.

On reading the above account of the experiments of Messrs. Janoyer and Gauthier, the writer of this article induced the furnace manager of the Blain Iron Works to increase the yields of lime on one of his furnaces to as great an extent as in his judgment it would bear, and when the furnace was under the full influence of the excess of flux to forward him samples of the gray pig for analysis. The following results show that, contrary to the statement of MM. Janoyer and Gauthier, no advantage, as regards a diminution in the amount of silicon, was thereby obtained, the proportion of that element being not perceptibly altered, though there is a slight diminution observable in the percentage of sulphur.

<table>
<thead>
<tr>
<th>Gray pig, with usual burden of lime</th>
<th>Gray pig, with extra burden of lime</th>
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</thead>
<tbody>
<tr>
<td>Sulphur</td>
<td>0.067</td>
</tr>
<tr>
<td>Silicon</td>
<td>2.990</td>
</tr>
</tbody>
</table>

As the presence of silicon in pig-iron affects in a remarkable degree the yield as well as the strength of puddled bars, it is of importance that this element should be removed as effectually as possible by a refining process before the crude iron is submitted to the puddling process. Pigs with 3 per cent. of silicon give about 6 per cent. of silica, and this requires somewhere about 12 per cent. of iron to form a cinder sufficiently fluid to allow the puddled iron to become aggregated into balls; this can of course be obtained only by burning that amount of iron in the puddling furnace after the expulsion of the carbon, and while the mass is in a powdery state. This powdery mass is composed of small granules of iron mixed up with a glossy fusible cinder. The puddler turns over this mass repeatedly to expose the iron to the oxidizing influence of the furnace; the silica, now taking up sufficient oxide of iron to give it fluidity, begins to separate from the iron, and forms a pool at the bottom. After some time the puddler, finding the mass of cinder accumulating pretty fast, makes the first attempt to "ball up." In order to save as much iron as possible, he keeps the deeper down and works the powdery mass at as low a red heat as possible. The balls, even when made, will not bear much heat under the hammer without falling to pieces, hence an imperfect weld in the hammered mass and rolled bar is the result, and although the iron may be chemically pure it is deficient in strength. By prolonging the process and wasting more iron, there is no doubt but that the iron might be improved, for the cinder
would become richer in oxide, more fluid, and consequently offer less resistance to a perfect weld. Iron, on the contrary, with a small percentage of silicon may be “balled up” directly it is “dried,” and the short time required for that operation can be conducted at the highest heat of the furnace. A good welding of the mass is the consequence: such iron is strong, and the labor of the puddler in obtaining it is much less than in the former case. Every pound of silica must have twice its weight of iron to form a cinder sufficiently rich in oxide to allow the particles of iron to become properly agglutinated. Such being the influence of silicon on both the yield and the strength of wrought iron, and such being the waste attendant on its removal in the refinery, it becomes an object of much practical importance to prevent as far as possible the formation of a silicate of iron in the blast furnace, and the observations of M. Janyer and Gauthier on this point require careful verification.

Manganese.—The presence of this element in pig-iron does not appear to exert much influence either for good or for bad on the quality of the metal, and even when it exists in quantity amounting to 4 or 5 per cent. in the crude iron, it disappears almost entirely during the conversion of the cast-iron into wrought or malleable. It has already been observed that the cinder from iron smelted from manganiferous ores contains, generally speaking, more sulphur than slags or cinders from iron ores containing no manganese. We have had numerous opportunities of confirming this, and have therefore on this account alone attached much importance to the existence of manganese in iron ores; but our attention has more recently been directed to another point which we think especially worthy of notice of iron manufactories, namely, to the almost perfect removal of phosphorus from pig-iron containing a very large proportion of that element, and at the same time a high percentage of manganese. As our experiments on this important point are still in progress, we shall merely here quote a few in illustration of the purifying action we have alluded to.

Iron made from a highly phosphorized ore containing no manganese:

<table>
<thead>
<tr>
<th>Phosphorus (per cent.)</th>
<th>Manganese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig</td>
<td>3.05</td>
</tr>
<tr>
<td>Puddled bar</td>
<td>0.888</td>
</tr>
<tr>
<td>Rough down bar</td>
<td>0.572</td>
</tr>
</tbody>
</table>

The finished bar was cold short in the highest degree; it was, in fact, nearly worthless.

Iron made from a highly phosphorized ore containing a large percentage of manganese:

<table>
<thead>
<tr>
<th>Phosphorus</th>
<th>Manganese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig</td>
<td>2.60</td>
</tr>
<tr>
<td>Puddled bar</td>
<td>0.30</td>
</tr>
<tr>
<td>Rough down bar</td>
<td>0.30</td>
</tr>
<tr>
<td>Finished bar</td>
<td>0.11</td>
</tr>
</tbody>
</table>

The iron was carefully watched during the puddling process. It melted very thin, and took rather more work than usual; as soon as the boiling commenced it was very violent, the metal forcing itself out of the door hole until it was checked. When it “came to nature,” as the workmen term it, it worked beautifully and stood any amount of heat; in fact, the heat could with difficulty be raised to the requisite degree. The yield was 22 cwts. 2 qrs. 24 lbs. of pig to produce 1 ton (of 20 cwts.) of puddled bar; this is about the yield of good mine iron when properly puddled. The finished bar exhibited none of the cold short quality, it was exceedingly ductile, indeed excellent horseshoes were made from it. The puddling cinder had the following composition:

| Silica   | 8.240 |
| Protoxide of iron | 70.480 |
| Oxide of manganese | 12.800 |
| Phosphoric acid | 7.660 |
| Sulphur | 335 |

99.715

Other observations have shown that highly manganiferous pig (without phosphorus) is puddled with difficulty, and sometimes with considerable waste, so that the advantages of an alloy of manganese would seem to be confined to those varieties of crude iron into the composition of which phosphorus largely enters.

The Conversion of Crede or Carborized Iron into Malleable Iron.—This is effected by one or more operations, which are necessarily of an oxidizing nature, the object being to eliminate from the cast-iron the carbon in the form of carbonic oxide gas, and the silicon, sulphur, phosphorus, and other foreign bodies in the form of oxidized products, which pass either partially or wholly into the scoria or cinders. The pig-iron is either subjected to a preliminary decarbonization in the oxidizing blast hearth, or “refinery,” and the opera-
tion thus commenced afterwards completed in the oxidizing air-furnace, or "puddling furnace," or the complete conversion of the crude iron is effected by one operation in the puddling furnace, by the process called "boiling." It is said (Blackwell) that, at several works abroad, the attempt to arrest the progress of decarburization in the puddling or boiling furnace at that point in which the conversion has proceeded only so far as to leave the iron in the state of steel, or subcarbonet, has been successful, and that a valuable natural or puddled steel, not requiring cementation before conversion into refined or cast steel, has been the result.

**English Method of refining.**—The finery furnace is composed of a body of brick-work, about 9 feet square, rising but little above the surface of the ground. The hearth, the bottom of which is of millstone grit, placed in the middle, is 23 feet deep; it is rectangular, being in general 3 feet by 2, with its greatest side parallel to the face of the tuyères, and it is made of cast-iron in four plates. On the side of the tuyères there is a single brick wall, on the three sides sheet-iron doors are placed, to prevent the external air from cooling the metal, which is almost always worked under an open shed or in the open air, but never in a space surrounded by walls. The chimney, from 15 to 18 feet high, is supported upon four columns of cast-iron; its lintel is 4 feet above the level of the hearth, in order that the laborers may work without restraint. The air is supplied by the blowing cylinders which supply the blast furnace, and enter the hearth through 6 tuyères, so arranged that the current issuing from those on the opposite sides of the crucible are not disposed in the same plane. These tuyères, like those in the furnaces in which cast-iron is made, are provided with double casings, through which a current of cold water is constantly flowing, and each pipe is furnished with a suitable stop-valve for regulating the velocity of the blast. The tuyères are placed at the height of the lip of the crucible or hearth, and are inclined towards the bottom, at an angle of from 25° to 36°, so as to point upon the bath of melted metal as it flows. The quantity of air blown into the finery is considerable, being nearly 400 cubic feet per minute for each finery. The ground plan of a finery is shown in fig. 347, a being the hearth, b the tapping hole, c the chill mould, and a a a a a a the nozzles of the tuyères. The operation of refining crude iron is conducted as follows: A fire is lit in the centre of the hearth, which is first urged by a gentle blast; a charge of pig, about 2 tons, is then laid on, and the whole is covered up dome-form with a heap of coke; the full power of the blast is now turned on, the cast-iron melts, and flowing down gradually collects in the crucible, more coke being added as the first quantity burns away. The operation proceeds by itself, the melted metal is not stirred about as in some modes of refinery, and the temperature is always kept high enough to preserve the metal liquid. During this stage the coals are observed continually heaving up, a movement due in part to the action of the blast, but in part to an expansion caused in the metal by the discharge of carbonic oxide gas. When all the pig-iron is collected at the bottom of the hearth, which happens in about two hours, it is blown vigorously for some time longer, the tap-hole is opened, and the fine metal runs out with the slag into the chill mould, or pit, as it is called, which has been previously washed with a thin clay liquid, to prevent the refined metal from adhering to its surface. The chill mould is in a prolongation of the tapping hole; it is a heavy cast-iron trough, about 10 feet long, 8 feet broad, and 2 to 2½ inches deep. The slag, from its inferior specific gravity, forms a crust on the surface of the metal; its separation is facilitated by throwing cold water in large quantities on the fluid mass immediately that the entire charge has left the refinery. This sudden chilling of the metal makes it exceedingly brittle, so that it can be broken into smaller pieces by heavy hammers, for the subsequent operation of puddling. The refined metal is very white, hard, and brittle, and possesses in general a fibrous radiated texture; or sometimes a cellular, including a considerable number of small spherical cavities, like a decomposed amygdaloid rock. The loss of iron in the refinery process is very large, varying from 10 to 20 per cent. In the Welsh iron works, 1 ton of white iron takes from 1¼ to 2 hours to refine, the consumption of coke being from 6 to 8 cwts and the loss about 3 cwts. Grey iron takes from 7 to 9 cwts. of coke per ton, the time required to refine being from 2½ to 3 hours, and the loss of iron per ton 4 cwts. The pig-iron to be decarburized in the finery is frequently mixed with rich silicates, (forge cluders,) and occasionally with oxides of
IRON.

iron, the object being to protect the melted metal in some degree from the oxidizing effects of the blast, and to rest on the carbon which it contains. The quantity employed depends on the degree to which the pig-iron is carbonized. The crude iron from which wrought iron of the best quality is produced, is that possessing a medium degree of carbonization, or what is generally termed gray pig-iron. White iron, which possesses an inferior degree of fluidity to gray pig-iron, and which comes as it is termed more rapidly to nature, is that quality which is most generally employed in the manufacture of wrought iron, especially when the conversion is effected in the single operation of boiling in the puddling furnace; but this species of pig-iron being the result of imperfect reactions in smelting, is always more impure than gray iron obtained from the same materials, and does not produce wrought iron of the best quality.

The coke employed in the refinery should be as free as possible from shale, and should contain only a low percentage of ash; it should especially be free from sulphur of iron, which it often contains in considerable quantity, as it is found that nearly the whole of this sulphur enters into combination with the metal, and does not pass off in the slags.

Reineries are sometimes worked on hot fluid iron, run direct from the hearth of the blast furnace, a considerable saving, both of time and fuel, being thereby effected. Various proposals have been patented for the employment of fluxes to assist in the removal of the impurities of cast-iron both in the refining and puddling furnace. Thus Mr. Hampton patented, in 1855, a flux, prepared by slaking quicklime with the solution of an alkali, or alkaline salt. MM. Du Motay and Fontaine propose, in a patent secured in 1856, to purify and decarbonate iron in the refining and puddling furnace, by the employment of fluxes prepared from the scoria of the puddling furnace, from oxides of iron and silicates or carbonates of alkalies, or other bases. Mr. Pope (1856) proposes to add the residue obtained by the distillation of Baghead or Torbane mineral, or any similar material, as is employed in the refining of iron. Mr. Sanderson, of Sheffield, (1856), employed for the refining of iron such substances as sulphate of iron, capable of disengaging oxygen or other elements, which will act upon the silicium, aluminium, &c., contained in the metal. These and various other schemes have been suggested with the object of lessening the enormous waste which pig-iron undergoes on its passage through the refinery; for as the process is at present conducted, the partial elimination of the carbon, sulphur, phosphorus, &c., is only effected at the expense of a large quantity of iron, which is oxidized by the blast, and passes in the form of silicate into the slag; the desideratum is the discovery of some method of reducing the oxide of iron, and substituting for it some other base, which will form with silica a sufficiently fusible silicate. Mr. Blackwell suggests that the decarbonation of pig-iron might be effected by remelting it in a cupola furnace, either alone, or with minerals containing nearly pure oxides of iron; the oxide of iron would be reduced by the carbon of the pig-iron, while the silicates of the fuel, with the silica, alumina, and other easily oxidizable alloys eliminated from the crude iron, would be separated in the form of fusible earthy glass. The employment of steam as a purifying agent for crude iron has been patented by several persons. Mr. Nasmyth in 1854 obtained a patent for the treatment of pig-iron in the puddling furnace with a current of steam, the steam being introduced into the lower part of the iron, passes upwards, and meeting with the highly heated metal undergoes decomposition, both elements acting as purifying agents. The steam employed is at a pressure of about 5 pounds per square inch, and passes into the metal through a species of hollow rabble, the workman moving this about in the fused metal until the mass begins to thicken, which occurs in from five to eight minutes after the introduction of the steam; the steam pipe is then removed and the puddling finished as usual.

The advantages are said to consist in the time saved at each heat or puddling operation, (from ten to fifteen minutes;) the very effective purification of the metal; and the possibility of treating highly carbonized pig-iron at once in the puddling furnace, the preliminary refining being thus avoided. In October, 1855, Mr. Bessemer patented a somewhat similar process for the conversion of iron into steel, the steam highly heated, or a mixture of air and steam, being forced through the liquid iron run from the furnace into skittle pots, steam being used only at an early stage of the process, and the treatment finished with heated air. In the early part of the same year Mr. Martien, of New Jersey, obtained a patent for a partial purification of crude iron, by causing air or steam to pass up through the liquid metal, as it flows along gutters from the top hole of the furnace or fluey forge; and he subsequently proposed to include with the air or steam, other purifying agents, such as chlorine, hydrogen, and coal gas, oxides of magnesia, and zinc, &c. Other methods of treating crude iron with air and steam were made the subjects of patents by Mr. Bessemer in December 1855 and January 1856. In October a patent for the employment of steam in admixture with cold blast in the smelting furnace and lining forge, was obtained by Messrs. Armstrong and Lee, of Leeds, and in April next, Mr. George Parry, of the Ebbw Vale Iron Works, for the purification of iron by means of highly heated steam. The fluid iron is allowed to run into a reverberatory furnace previously heated, and the steam is made to impinge upon it from several tuyères, or to pass
through the metal. Steel is to be obtained by treating highly carburised iron with the steam, and then running it into water, and fusing it with the addition of purifying agents, or adding to it in the furnace a small quantity of clay; and afterwards about 10 or 15 per cent. of calcinedspathose ore. Mr. Parry observing that when steam was sent through the molten iron, as in Mr. Nasmyth’s process, the iron quickly solidified, conceived the idea of communicating a high degree of heat to the steam by raising the steam pipe a couple of inches above the surface of the metal, so that it might be exposed to the intensely heated atmosphere of the furnace; and also of inclining the jet at an angle of 45°, so as to give the molten mass a motion round the furnace while the pipe was maintained in the same position at a little distance beyond the centre; when this was done, in a few minutes the iron began to boil violently, the rotary motion of the fluid bringing every part of it successively into contact with the highly heated mixture of steam and atmospheric air, and solidification taking place. Having thus ascertained the proper way of using steam as a refining agent, it occurred to Mr. Parry that, as the presence of silicium in the pigs for puddling affects in a remarkable degree the yield of iron, as well as its strength, it is a matter of consequence that this element should be removed as completely as possible previous to the puddling operation; the steaming of the iron would probably therefore be more profitably applied in the refinery than in the puddling furnace. Pig-iron containing 5 per cent. of silicium gives 6 per cent. of silica, which, to form a cinder sufficiently fluid to allow the balling up of the iron, would require from 10 to 12 per cent. of iron; and this can, of course, be obtained by burning that amount of iron in the puddling furnace, after the expulsion of the carbon, and while the mass is in a powdery state. The superheated steam is injected on the surface of the iron in the refinery by water tuyères, similar to those used for hot blast at smelting furnaces; they are inclined at an angle of about 45°; some are inserted at each side of the door of the furnace, and are pointed so as to cross each other, and give the iron a circulating motion in the furnace. The tuyères are from \( \frac{1}{2} \) to \( \frac{1}{2} \) an inch in diameter; a little oxide of iron or silicate in a state of fusion on the surface of the iron accelerates the action, as in common refineries, and increases the yield of metal, but to a much greater extent than when blasts of air are used. The steam having been turned on, the mass of iron commences circulating around the inclined tuyères, and soon begins to boil, and the action is kept uniform by regulating the flow of the steam. The most impure oxides of iron may be used in this process, such as tap cinder or hammer slag from puddling furnaces, without injury to the quality of the refined metal made; the large quantities of sulphur and phosphorus which they contain being effectually removed by the detergent action of the heated steam. When 4 cwt. of cinders are used to the ton of pig, 20 cwt. of metal may be drawn, the impurities in the pig being replaced by refined iron from the cinders.

We have had several opportunities of witnessing this beautiful refining process at the Ebbw Vale Iron Works, and have made the following analysis of the cinders and metal, which fully bears out the above statements:

<table>
<thead>
<tr>
<th></th>
<th>Pig iron</th>
<th>Refined metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Silicon</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Silex</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulphur</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Manganese</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Forge cinders</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cinder run out of the refinery</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

A ton of grey iron may be refined by steam in half an hour, using seven jets of steam \( \frac{1}{2} \) of an inch in diameter, and with a pressure of from 30 to 40 lbs.; the temperature of the steam being from 600° to 700° F., the surfaces of the tuyères being 2 or 3 inches above the surface of the iron. As the fluidity of the metal depends upon the heat which it is receiving from the combustion of the fuel in the grate, and not on any generated in it by the action of the steam, it is evident that the supply of the latter in a given time must not exceed a certain limit, or the temperature of the fluid iron will become reduced below that of the furnace. This, however, partly regulates itself, and does not require much nicety in the management, for, if too much steam be given, the ebullition becomes so violent as to cause the cinders to flow over the bridges, giving notice to the refiner to slack his blast. The "forge cinders" used in the steam refinery contain 65 per cent. of iron; the "run out" cinder contains only 26; 40 per cent. of iron, or thereabouts, have therefore been converted into refined metal, and the resulting cinder is as pure as the ordinary Welsh mine, with its yield of 25 per cent. of iron. The following is the result of one week’s work of the steam refinery:
The quantity of cinder (puddling) used was \( \frac{3}{4} \) cwt. per ton of pig. When 1½ cwt. of cinders were used to 1 ton of pig, the yield was invariably 20 cwt. over a make of about 100 tons.

Refining by gas. (German method.)—The most simple form of gas reverberatory furnace is that known as Eck's furnace, which is employed at the government works of Gleiwitz and Königshütte, for refining iron made on the spot. The following description and plan of the furnace is extracted from a report to the secretary of state for war, from the superintendent of royal gun factories, Colonel Wilmot, R.A., and the chemist of the War Department, Professor Abel.

The gas generator (which replaces the fireplace of the ordinary reverberatory furnace) is an oblong chamber, the width of which is 3 feet 9 inches, and the height from the sole to the commencement of the sloping bridge 6 feet 4 inches. It tapers slightly towards the top, so as to facilitate the descent of the fuel, which is introduced through a lateral opening near the top of the generator. Its cubic contents are about 44 feet.

The air necessary for the production of the gas is supplied by a feeble blast, and enters the generator from the two openings or tuyères of a long air-duct of iron plate (Figs. 348, 349, 350) fixed at the back of the chamber, near the bottom. The space between the air-duct and the sole of the chambers serves as a receptacle for the slag and ash from the fuel. There are openings on the other side of the chamber, opposite the tuyères, which are generally closed by iron plugs, but are required when the tuyères have to be cleaned out. There is an opening below the air-duct, through which fire is introduced into the chamber, when the furnace is set to work, and which is then bricked up, until at the expiration of about 14 days it becomes necessary to let the fire die out, when the slag and ash which have accumulated on the sole of the chamber are removed through this opening.

The hearth of the furnace is constructed of a somewhat loamy sand; its general thickness is about 6 inches; its form is that of a shallow dish, with a slight incline towards the top hole; the iron is prevented from penetrating through the hearth by the rapid circulation of cold air below the fire-bridge and the plate of the hearth.

Figs. 351 and 352 represent the upper oblong air-chest provided with a series of tuyères, which enter the top of the furnace just over the fire-bridge at an angle of 30°. The air forced into the furnace through these tuyères serves to inflame and burn the gases rushing out of the generator, and the direction of the blast throws the resulting flame down upon the metal on the hearth, in front of the bridge. This air-chest communicates, like the other one, by pipes, with the air accumulator of the neighboring blast furnace. The amount of pressure employed is about 4 lbs.; but the supply of air, both to the generator and the inflammable gases, admits of accurate regulation by means of valves in the connecting pipes. There is an opening in the arch at both sides of the furnace, not far from the bridge, into which, at a certain stage of the operations tuyères are introduced, (being placed at an angle of 25°) also connected with the blast apparatus and provided with regulating valves.

The refining process is conducted as follows:—The hearth of the furnace having been constructed or repaired, a brisk coal fire is kindled in the generator, through the opening at the bottom, which is afterwards bricked up. About 20 cubic feet of coal are then introduced from above, and the necessary supply of air admitted to the generator through the lower air-duct. When these coals have been thoroughly ignited, the generator is filled with coals, and a very moderate supply of air admitted through the tuyères below, (for the generation of the gas,) and those over the bridge, (for its combustion,) until the furnace is dried, when the supply of air at both places is increased, so as to raise the hearth to the temperature necessary for baking it thoroughly, upon which, about 40 cwt. of iron are introduced, the metal being distributed over the whole hearth as uniformly as possible, and the size of the pieces being selected with the view to expose as much sur-
face as possible to the flame. The fusion of the charge of metal is effected in about three hours, the coal used amounting to about \( \frac{3}{4} \) cubic feet per hour. The gas generator is always kept filled with coal, and the supply of air admitted from below is diminished by a regulation of the valve, whenever fresh coal is supplied, as the latter, at first, always yields gas more freely. The arrangement of the upper row of tuyères effects the combustion of gases just as they pass from the generator on to the hearth. The hottest portion of the furnace is of course near the fire-bridge, i. e., where the blast first meets with the gases. During the melting process the iron is shifted occasionally, so that the
cooler portion near the flue may in its turn become melted without loss of time. When the iron is ascertained to be thoroughly fused, about 5 lbs. of crusted limestone are thrown over its surface for the purpose of converting the dross which has separated into fusible slag. The two side tuyères are now introduced into the furnaces through the openings above alluded to, the width of the nozzle employed depending upon the power of the blast used. The air rushing from these tuyères impinges with violence upon the
iron, and, the two currents meeting, an eddying motion is imparted to the fused metal. In a short time the motion produced in the mass is considerable; the supernatant slag is blown aside by the blast, and the surface of the iron thus exposed undergoes refinement, while it changes continually, the temperature of the whole mass being raised to a full white heat, by the action of the air. The iron is stirred occasionally, in order to insure a proper change in the metal exposed to the action of the blast. A showel of limestone is occasionally thrown in, (the total quantity used being about 1 per cent. of the crude iron employed.) The slag produced is exceedingly fusible, and is allowed to remain in the furnace until the metal is tapped, and on cooling it separates from it completely.

The duration of the treatment in this furnace after the metal is fused, varies from two hours and a half to five hours, according to the product to be obtained. For the preparation of perfectly white iron, the treatment is carried on for five hours. A sample is tapped to examine its appearance, when it is believed to be sufficiently treated.

When the charge is to be withdrawn from the furnace, the side tuyere nearest the tap hole is withdrawn, so that the blast from the opposite tuyere may force the metal towards the hole. The fluid iron, as it flows from the tap hole, is fully white hot, and perfectly liquid; it chills, however, very rapidly, and soon solidifies. A few pails of water are thrown upon those portions of the metal which are not covered with the slag, which flows out of the furnace, the object being to cool it rapidly, and thus prevent the oxidation of any quantity of iron. The loss of metal during the treatment is said not to exceed 5 per cent.

With regard to the purification which the iron undergoes in the gas reverberatory furnace, it appears to be confined chiefly to the elimination of carbon and silicium, the amount of sulphur and phosphorus undergoing but little alteration, as appears from the following analysis (Abel):

<table>
<thead>
<tr>
<th></th>
<th>Pig iron.</th>
<th>Refined iron.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicium</td>
<td>4.06</td>
<td>0.62</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.56</td>
<td>0.30</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.04</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Nevertheless the iron thus refined is highly esteemed for all castings which are required to possess unusual powers of resistance; some experiments made to ascertain the comparative strain borne by the refined metal, and the same metal as obtained from the blast furnace, showed the strength of the former to be greater by one half than that of the latter.

The operation of puddling.—In the years 1788 and 1784, Mr. Henry Cort of Gosport obtained two patents, one for the puddling, and the other for the rolling of iron, "discovery," says Mr. Scrivenor, "of so much importance in the manufacture, that it must be considered the era from which we may date the present extensive and flourishing state of the iron trade of this country."

The object of Mr. Cort's processes was to convert into malleable iron, cast or pig iron, by means of the flame of pit-coal in a common air furnace, and to form the result into bar by the use of rollers in the place of hammers. The process was managed in the following manner: —"The pigs of cast iron produced by the smelting furnaces are broken into pieces, and are mixed in such proportions according to their degree of carbonization, that the result of the whole shall be a gray metal. The mixture is then speedily run into a blast furnace, where it remains a sufficient time to allow the greater part of the scorie to rise to the surface. The furnace is now tapped, and the metal runs into moulds of sand, by which it is formed into pigs, about half the size of those which are broken into pieces. A common reverberatory furnace heated by coal is now charged with about 23 cwt. of this half-refined gray iron. In a little more than half an hour, the metal will be found to be nearly melted; at this period the flame is turned off, a little water is sprinkled over it, and a workman, by introducing an iron bar through a hole in the side of the furnace, begins to stir the half-fluid mass, and divide it into small pieces. In the course of about 50 minutes from the commencement of the process, the iron will have been reduced by constant stirring to the consistence of small gravel, and will be considerably cooled. The flame is then turned on again, the workmen continuing to stir the metal, and in three minutes' time the whole mass becomes soft and semifluid, upon which the flame is then turned off. The hottest part of the iron now begins to heave and swell, and emit a deep lambent blue flame, which appearance is called fermentation; the heaving motion and accompanying flame soon spread over the whole, and the heat of the metal seems to be rather increased than diminished for the next quarter of an hour; after this period the temperature again falls, the blue flame is less vigorous, and in a little more than a quarter of an hour the metal is cooled to a dull red, and the jets of flame are rare and faint. During the whole of the fermentation the stirring is continued, by which the iron is at length brought to the consistence of sand; it also approaches nearer to the malleable state, and in consequence adheres less than at first to the tool with which it is stirred. During the next half hour the flame is turned off and on several
times, a stronger fermentation takes place, the lambent flame also becomes of a clearer and lighter blue; the metal begins to clot, and becomes much less fusible and more tenacious than at first. The fermentation then by degrees subsides; the emission of blue flame nearly ceases; the iron is gathered into lumps and beaten with a heavy-headed tool. Finally, the tools are withdrawn, the apertures through which they were worked are closed, and the flame is again turned on in full force for six or eight minutes. The pieces being thus brought to a high welding heat, are withdrawn and shingled; after this they are again heated and passed through grooved rollers, by which the scorias are separated, and the bars thus forcibly compressed acquire a high degree of tenacity." But this mode of refining did not produce altogether the desired result. It was irregular; sometimes the loss of iron was small, but at others it was very considerable, and there were great variations in the quality of the iron, as well as in the quantity of fuel consumed. These difficulties were, however, removed by the introduction of the coke finery by the late Mr. Samuel Homfray, of Penydarren, upon which the puddling and balling furnaces came immediately into general use, with the addition of rollers in lieu of hammers.

Mr. Cort's first patent, which is for "rolling," is dated 17th January, 1783; his second, that for "puddling," is dated 13th February, 1784. It has been attempted, though we think very unjustly, to detract from Cort's merits as an original inventor, by referring to the patents of John Payne and Peter Onions, dated respectively 21st November, 1728, and 7th May, 1783. The first was to a certain extent, undoubtedly, a patent for "rolling;" for the bars rendered mallcable by a process indicated, are "to pass between the large metal rollers which have proper notches or furrows upon their surface." but there is no proof that any practical use was made of Payne's process, while that of Cort was almost immediately and universally adopted: it may be true, therefore, that Cort was the rediscoverer and not the actual discoverer of the process of rolling, but this in no way detracts from his merit, inasmuch as, by his improvements, he was enabled to make available that which was previously useless. The same observation applies to the patent of Onions, which to a certain extent anticipated that of Cort for puddling. Onions employed two furnaces—a common smelting furnace, and a furnace of stone and brick, bound with iron work and well annealed, into which the fluid metal was received from the smelting furnace. When the liquid metal had been introduced into the second furnace by an aperture, it was closed up and subjected to the heat of fuel and blast from below, until the metal became less fluid, and thinned out into a kind of paste; this the workman by opening a door turns and stirs with a bar of iron, and then closes the aperture again, after which blocks and fire are applied until there is a finished metal; the adherent particles of iron are collected into a mass, reheated to a white heat, and forged into mallcable iron. That the process of puddling is here indicated there can be no doubt, but the actual operation was impracticable until Henry Cort invented the furnace in which it could be conducted.

Neither Mr. Cort nor his family appear to have derived much advantage from his important discoveries—discoveries which changed us at once from dependent importers of iron into vast exporters to every country of the world, and which may be considered to have founded the iron industry of Great Britain. So long ago as 1811, the chief representatives of the trade assembled at Gloucester unanimously acknowledged their indebtedness to Mr. Cort for the improvements of which he was the author, and this acknowledgment has been repeated within the last twelve months by Robert Stephenson, Fairbairn, Haughton and Field, Cobett, Rendel, Sir Charles Fox, Bidder, Crawshay, Bailey, and many others. In working out his inventions, Cort is said to have expended a fortune of £20,000, and when his patents were completed, the leading ironmasters of the country contracted to pay him 10s. a ton for their use, so that he would not only have been repaid, but munificently rewarded, had he not unfortunately connected himself with a man named Adam Sellicoe, chief clerk of the Navy Pay Office, who proving to be a defaulter, committed suicide, having previously destroyed the patents and the agreement with ironmasters belonging to his partner, Henry Cort. Upon the death of Sellicoe, the premises, stock, and entire effects of Cort were sold by a summary process obtained by the Navy Pay Office, and the unfortunate man was thus completely ruined. For description of puddling furnace, see Iron, vol. 1.

The Puddling process.—Various patents have been taken out within the last four or five years for the employment of chemical agents to assist in the purification of iron in the puddling furnace. One of the latest is that of M. Charles Pauper of Chatellerault, who proposes to employ a cement composed of the following substances:—oxide of iron, 14 parts; highly aluminous clay, 30 parts; carbonate of potash, 1 part; carbonate of soda, 1 part. The iron is to be placed with the cement in layers, and heated in the furnace in the ordinary manner. After cementation it is welded, and then drawn into bars; it is stated to become thus as soft and tenacious as iron made from charcoal. Shaftain's compound, for which a patent was secured in 1835, is said by Overman to furnish very satisfactory results, and where competent workmen are employed, a good furnace is said
to make a heat in two hours, producing neither too much nor too little cinder in the furnace. The compound consists of common salt, 5 parts; oxide of manganese, 3 parts; fine white plastic clay, 2 parts. The pig is heated as in common operations. It is melted down by a rapid heat, the damper is closed, and the cinder and metal diligently stirred. In the mean time the above mixture, in small parcels of about half a pound, is introduced in the proportion of one per cent. of the iron employed; if, after this, the cinder does not rise, a hammer slag (rolling mill cinder) may be applied.

The "Boiling" process.—In this operation, which was the invention of Mr. Joseph Hall, pig iron is converted into malleable iron without the intervention of the refinery, and without any excessive waste: it is, therefore, of great value, especially as it allows of the use of better qualities of pig iron than those usually employed. The construction of the "boiling" furnace does not materially differ from that of the "puddling" furnace, except in the depth of the hearth, that is, in the distance from the work place below the door to the bottom plate, which, in the former, is double, or nearly so, that of the latter. In the puddling furnace the distance between the bottom and top seldom exceeds twenty inches, while in the boiling furnace it varies from twenty to thirty. In puddling the furnace is charged with metal alone, but in boiling cinder is charged along with the metal, and the temperature rises much higher. The bottom of the furnace is covered with broken cinders from previous workings, or with the tap cinder from the puddling furnace which has been subjected to a process of calcination in kilns; this material, which constitutes an admirable protection to the iron plates of the furnace, is called by the workmen "bull dog;" its preparation was patented by Mr. Hall in 1833. It is made in the following manner: the tap cinder from the puddling furnace is placed in layers in a kiln, and so arranged that a draught shall pass through from the fire holes on one side to those on the other: the kiln is filled up to the top with broken cinders, and over the whole is laid a layer of coke; about the third or fourth day, the more fusible part of the cinder begins to run out of the bottom holes, leaving in the kiln a fine rich porous silicate of iron, which is the substance used for lining the boiling furnace, the fluid portion being rejected. In 8 or 10 hours the "bull dog" is melted by the intense heat of the furnace, covering the bottom, and filling up all the interstices in the brickwork; the heat is now somewhat lowered by diminishing the draught, and the charge of pig (from 3½ to 4½ cuwts.) introduced in fragments of a convenient and uniform size, together with 30 or 40 lbs. of cinder; the doors of the furnace are now closed, and all access of cold atmospheric air prevented, throwing fine cinder or hammer slag round the crevices, and stopping up the work hole with a piece of coal. In about a quarter of an hour the iron begins to get red-hot; the workman then shifts the pieces so as to bring the whole to a state of uniformity as regards heat. In about half an hour the iron begins to melt; it is constantly turned over, and at intervals of a few minutes cinder is thrown in; the surface of the mass is seen to be covered with a blue flame; it soon begins to rise; a kind of fermentation takes place beneath the surface, and the mass, at first but 2 inches high, rises to a height of 10 or 12 inches, and enters into violent ebullition. During the time that this "fermentation" is taking place, constant stirring is required to prevent the iron from settling on the bottom. The boiling lasts about a quarter of an hour; after which the cinder gradually sinks, and the iron appears in the form of porous spongy masses of irregular size, which are constantly stirred to prevent their adhering together in large lumps, to facilitate the escape of the carbon, and to separate the cinder, which, when the operation has been successfully conducted, flows over the bottom apparently as liquid as water. The iron is now "baled up," as in the operation of puddling. The objections to the boiling process are: the wear and tear in the furnace which occurs in treating gray pig iron, particularly that of the more fluid description; the slowness of the operation, and the amount of manual labor which it entails to produce good results. In some works the crude iron is run directly into the boiling furnace from the blast furnace, by which much saving of coal is effected, and a product of a more uniform quality obtained; but the labor of the workman becomes more oppressive from the additional heat to which he is subjected from the close proximity of the blast furnace. Ironmasters are not agreed as to the respective merits of the "boiling" and "puddling" systems; some maintain that the former is more economical than the latter, which involves "refining;" others think that boiling iron has a tendency to communicate to it the "red short" quality. According to the observations of Mr. Truran, in several works where both methods are employed, the largest quantity of iron is first passed through the refinery.

Mr. Hall, the inventor of the boiling system, in descanting on the merits of his process, describes how, with the same pig, the iron may be made weak and cold short; or fine and strong. He made three puddles. The first, an expanse, then puddle agreeably to the old plan on the sand bottom; that is, melt it as cold as possible; drop the damper quite close before the iron is all melted, dry the iron as expeditiously as may be, with a large quantity of water; and, lastly, proceed to ball
in a proper number of "young" balls; the result will be a very inferior quality of manufactured iron. On the other hand, to produce a malleable iron of very superior quality, first charge the furnace with good forge pig iron, adding, if required, a sufficiency of flux, increasing or diminishing the same in proportion to the quality and nature of the pig iron used. Secondly, melt the iron to a boiling consistency. Thirdly, clear the iron thoroughly before dropping down the damper. Fourthly, keep a plentiful supply of fire upon the grate. Fifthly, regulate the draught of the furnace by the damper. Sixthly, work the iron into one mass, before it is divided into balls; when thus in balls, take the whole to the hammer as quickly as possible, after which roll the same into bars. The bars, being cut into lengths, and piled to the desired weights, are then heated in the mill furnace, welded and compressed by passing through the rolls, and thus furnished for the market. In this way, from the pig to the finished mill bar, one entire process, that of the refinery, is saved. Mr. Hall states that, by his process, he can obtain malleable iron of any character, (presuming that the ores from which the pig is smelted are of good quality,) from the softness of lead to the hardness of steel, and further that he can exhibit different qualities in the same bar, one end being crystalline, nearly as brittle as glass, the other end equal to the best iron that can be produced for fibre and tenacity, while the middle exhibits a character approximating to both; and as a further illustration of the excellence of the iron that may be made by the "pig boiling" process, he refers to a specimen in the Geological Museum, Jermyn Street, London, labelled "Specimen of two and a quarter inch round iron, tied cold, manufactured at the Bloomfield Iron Works, Tipton, Staffordshire." This specimen has been called a "Staffordshire knot." It was made from a bar two inches and a quarter in diameter, and nearly seven inches in circumference; also to a "Punched Bar," half inch thick, made at one process for the smithy, commencing with a half-inch punch, and terminating with one six and a half, without exhibiting the slightest fracture.

Mr. Hall was led to the discovery of the "boiling" principle, by noticing the exceedingly high fusion which took place on subjecting puddling furnace slag to a high degree of heat, and the excellence of the bloom of iron produced by the operation; it occurred to him, that if such good iron could be made from cinder alone, a very superior product ought to be obtained from good pig iron, with equally good fluxes, and the result of experiments fully answered his expectation, though for a long time he was unable to make his discovery practically useful, on account of the difficulty of getting furnaces constructed capable of rendering the intense heat required, and the corroding action of the fluxes. Puddling furnaces were then made of brick and clay, with sand bottoms. He succeeded at last by lining the interior of the furnace with iron, and protecting it with a coating of prepared tap cinders.

In America, the "pudding" and "boiling" processes are both in use. Overman gives preference to the latter as being the most profitable, but it can only be employed to a limited extent for lack of cinder; in a rolling mill forge, therefore, half the furnaces are employed for boiling, and half for puddling, the latter supplying cinder for the former.

In the eastern States, where the fuel is anthracite, double puddling furnaces are employed and a blast is used, the incombustibility of this variety of coal rendering it impossible to get the requisite heat by merely the draught of the chimney. Fig. 359 represents an anthracite furnace bisected vertically through the grate, hearth, and chimney. It differs from the ordinary puddling furnace chiefly in the greater depth of the grate, which is made to contain from twenty to twenty-four inches of coal, and in the lesser height of the chimney, which, as a blast is employed, need only be sufficiently high to carry the
hot gases out of the furnace; the letters $a$, $a$, $a$, $a$, indicate the position of the iron cross binders, which serve to bind together the cast-iron plates of the enclosure, and to prevent the sinking of the roof from the expansion and contraction of the brickwork.

The blast machines are fans, the best form of which is shown in Fig. 360. (Overman.) The wings of this fan are caused in a separate box; a wheel is thus formed, which rotates in the outer box; the figure shows a horizontal section through the axis. The wings are thus connected, and form a closed wheel, in which the air is whirled round, and thrown out at the periphery. The inner case, which revolves with the wings, is fitted as closely as possible to the outer case, at the centre near $a$, $a$, $a$. The speed of the wings is sometimes as much as 1,800 revolutions per minute. The motion of the axis is produced by means of a leather or india-rubber belt and a pulley. This variety of fan is used at the puddling furnaces at Ebbw Vale, where the fuel is small coal.

Fig. 361 is a horizontal section of the double anthracite puddling furnace. The grate measures 3 feet by 5. The width of the furnace externally is from 5½ to 6 feet. The hearth is usually 6 feet long. It has two work doors, one directly opposite the other. Two sets of workmen are required therefore at the same time; double the quantity of metal is charged, and the yield is twice that of a single furnace; the economy is in the room, fuel, and labor; one good puddler only being required to manage the operation. Double puddling furnaces are also used in several works in England, but as Mr. Tiffin observes, the economical advantages attending them in point of fuel are lost if the puddlers do not work well together; they must bring their heats to the respective stages simultaneously, for if one is kept waiting for a short period by the other, the loss in iron more than balances the reduced consumption of coal. This difficulty of obtaining men who will work well in concert has operated against the use of the double furnace, which would otherwise certainly supersede the single, as, combined with the process of running the iron in liquid from the blast furnace, the consumption of fuel is under the one-half of the quantity demanded with single furnaces working cold iron.

Puddling furnaces are sometimes constructed with what are called “water boshes.” The hearth is surrounded with heavy cast-iron plates, in which is formed a passage of an inch or an inch and a half bore, through which a current of cold water is caused to flow, the object being to protect the furnace from the destructive action of the heat and clinker. Overman found such furnaces to work well with fusible metal such as is produced from a heavy burden on the blast furnace, or from ores containing phosphorus; but with iron requiring a strong heat, such as results from a light burden on the blast furnace, or when it contains impurities firmly and intimately combined, puddling furnaces with cooled boshes failed to make good malleable iron.

We do not know whether the iron manufacturers in England will assent to the following proposition laid down by the American metallurgist, viz.: “That the smaller the amount of coal consumed, or the lower the temperature of the hearth in the blast furnace, the better will be the quality of the metal; that is, the more fit it will become for improvement in the puddling furnace. The advantage of heavy burden in the blast furnace, is not only that it reduces the first cost of the metal, but makes a far superior article for
subsequent operations. The worst cold short, or sulphurous metal, smelted by a low heat, is quite as good as the best metal from the best ore smelted by a high temperature. What ever may be thought of the latter part of this quotation, no iron manufacturer will deny that careful attention to the blast furnace is the best security of success in the puddling furnace, and that success in the one is in proportion to the economy observed in relation to the other; or that it is hopeless to attempt to improve in the puddling furnace pig iron made in a furnace that is constantly changing its burden and management; such iron is most advantageously disposed of by being worked up into coarse bar or railroad iron.

In the autumn of 1856 the attention of ironmasters and of the public generally was powerfully excited by a proposal from Mr. Bessemer to manufacture iron and steel from crude iron, without any fuel at all. The views of Mr. Bessemer were first communicated to the public in a paper read by that gentleman at the meeting of the British Association held at Cheltenham in August. From this paper the following extracts are taken, descriptive of the apparatus employed, and of the phenomena attending the conversion:

"The furnace is a cylindrical vessel of three feet in height, somewhat like an ordinary cupola furnace, the interior of which is lined with fire-bricks; and at about two inches from the bottom are inserted fire tuyere pipes, the nozzles of which are formed of well-burnt fire clay, the orifice of each tuyere pipe being about three-eighths of an inch in diameter. These are so put into the brick lining (from the outer side) as to admit of their removal or renewal in a few minutes when they are worn out. At one side of the vessel, about half way up from the bottom, there is a hole made for running in the crude metal; and on the opposite side a tap hole stopped with foam, by means of which the iron is run out at the end of the process. The vessel is placed so near the discharge hole of the blast furnace as to allow the iron to flow along a gutter into it. A small blast of air is required, capable of compressing air to about 8 lbs. or 10 lbs. to the square inch. A communication having been made between it and the tuyères, the converting vessel is in a condition to commence work. Previous, however, to using the cupula for the first time, it must be well dried by lighting a fire in the interior. The tuyères are situated nearly close to the bottom of the vessel; the fluid metal rises, therefore, some 18 inches or two feet above them. It is necessary, in order to prevent the metal from entering the tuyère holes, to turn on the blast before allowing the crude iron to run into the vessel from the blast furnace. This having been done, and the fluid iron run in, a rapid boiling up of the metal is heard going on within the vessel, the metal being tossed violently about, and dashed from side to side, shaking the vessel by the force with which it moves from the throat of the converting vessel. Flame will then immediately issue, accompanied by a few bright sparks. This state of things will continue for about 15 or 20 minutes, during which time the oxygen of the atmospheric air combines with the carbon contained in the iron, producing carbolic acid gas, and at the same time evolving a powerful heat. Now as this heat is generated in the interior of, and is diffused in innumerable fiery bubbles through, the whole fluid mass, the metal absorbs the greater part of it, and its temperature becomes immensely increased, and by the expiration of 15 or 20 minutes, the mechanically mixed carbon or graphite has been entirely consumed. The temperature is, however, so high that the chemically combined carbon now begins to separate from the metal, as is at once indicated by an immense increase in the volume of the flame rushing out at the throat of the vessel. The metal now rises several inches above its natural level, and a light frothy slag makes its appearance, and is thrown out in large foam-like masses. This violent eruption of cinder generally lasts 2 or 3 minutes, replacing the shower of sparks and cinder which always accompanies the boil.

"The rapid union of carbon and oxygen which thus takes place, adds still further to the temperature of the metal, while the diminished quantity of carbon present, allows a part of the oxygen to combine with the iron, which undergoes combustion, and is converted into oxide, at the excessive temperature that the metal has now acquired; the oxide, as soon as it is formed, undergoes fusion, and forms a powerful solvent of those earthy bases that are associated with the iron. The violent ebullition which goes on mixes most intimately the scorie and metal, every part of which is brought into contact with the fluid, which will thus wash and cleanse the metal most thoroughly from the silica and other earthy bases, while the sulphur and other volatile matters which cling so tenaciously to iron at ordinary temperatures, are drawn off, the sulphur combining with the oxygen and forming sulphurous acid gas. The loss in weight of crude iron during its conversion into an ingot of malleable iron was found on a mean of four experiments to be 12 1/2 per cent., to which will have to be added the loss of metal in the finishing rolls. This will make the entire loss probably not less than 18 per cent., leaving enough about 25 per cent. as the loss on the present process. A large portion of that metal is, however, recoverable, by treating with carbonaceous gases the rich oxides thrown out of the furnace during the boil. These slags are found to contain
innumerable small grains of metallic iron, which are mechanically held in suspension in the slags, and may be easily recovered by opening the tap hole of the converting vessel, and allowing the fluid malleable iron to flow into the iron ingot moulds placed there to receive them.

"The masses of iron thus formed will be perfectly free from any admixture of cinder, oxide, or any other extraneous matters, and will be far more pure and in a sounder state of manufacture than a pile formed of ordinary puddled bars. And thus it will be seen that by a single process, requiring no manipulation or particular skill, and with only one workman, from 3 to 5 tons of crude iron passes into the condition of several piles of malleable iron in from 30 to 55 minutes, with the expenditure of about ⅛ of the blast now used in a finery furnace with an equal charge of iron, and with the consumption of no other fuel than is contained in the crude iron. . . ."

"One of the most important facts connected with this new system of manufacturing malleable iron, is that all the iron so prepared will be of that quality known as charcoal iron, because the whole of the processes being conducted without the use of mineral fuel, the iron will be free from those injurious properties which that description of fuel never fails to impart to iron that is brought under its influence.

"At that stage of the process immediately following the boil, the whole of the crude iron has passed into the condition of cast steel of ordinary quality. By the continuation of the process, the steel so produced gradually loses its small remaining portion of carbon, and passes successively from hard to soft steel, and from soft steel to steely iron, and eventually to very soft iron; hence at a certain period of the process any quality of metal can be obtained."

The phenomena attending this novel process of iron-making are very well described in the above extract; and if we substitute for the words "a few bright sparks," the words "shower of bright sparks," poured out in enormous quantities, projected thirty or forty feet into the air, and falling on all sides in a thick shower," a good idea may be formed of the gorgeous display of pyrotechny which is exhibited. We must demur, however, to the statement that "the sulphur and other volatile matters present in the crude iron are drawn off," the fact being that the sulphur and phosphorus appear to have suffered little if any diminution, notwithstanding the excessive temperature and the powerful oxidizing action to which the iron has been subjected. Thus Mr. Abel found, in a specimen of Mr. Bessemer's product, from 0'4 to 0'5 per cent. of phosphorus, and from 0'05 to 0'06 per cent. of sulphur; the Blanavron pig, from which it was stated to have been prepared, containing 0'5 of the former and 0'06 of the latter; and in a sample, broken off from an ingot cast at Easter House, Sept. 1st, 1856, on which occasion we were present, and witnessed the whole process, we obtained 0'6 per cent. of phosphorus and 0'08 per cent. of sulphur; similar results have been obtained by other chemists. The carbon and silicon, on the other hand, are eliminated, the latter wholly so, while the quantity of the former is reduced to a few hundreds per cent.; we think also that Mr. Bessemer is mistaken in stating that the iron produced by his method contains "no admixture of oxide," for the specimens which we have had an opportunity of examining, presented unmistakable evidence of partial oxidation in the very centre of the ingot, nor do we see how it could well be otherwise.

It will easily be imagined that a process which, if successful, must have revolutionized the whole iron manufacture, was speedily subjected to a most careful and searching investigation; and, for some months after its announcement, the papers were filled with communications from all parts of the country, detailing experiments made on the large scale to test its value; the results, unfortunately for the ingenious projector, were unanimously unfavorable.

We quote first from the "Mining Journal" of Nov. 29, 1856:

"The Dowals Company appear to have thoroughly and impartially tested Mr. Bessemer's process, and the results obtained can only be regarded as a total failure. . . . A Bessemer furnace was erected, and acted excellently as far as the process was concerned, but failed to produce any thing like malleable iron. The iron used was from clay-ironstone, Whitehaven haematite, and small portions of forge cinders, in the proportions usually employed in Wales for rails and merchant iron. After the metal had been subjected to a blast of 8 lbs. pressure, it was withdrawn and taken to the 'squeezer,' as is usual with puddled blooms, to take out the dross and unite the particles of metal. Instead of acting like puddled iron, Mr. Bessemer's bloom under the squeezer was a mere mass of red-hot friable matter, and, from its crumbling and non-cohesion, was with difficulty formed into an ingot; when passed through the rolls it broke on the drawing side as easily as very red short iron, to the infinite gratification of the men, who greeted each failure with hearty cheers. By mixing slag with the metal, a slight improvement was effected, but, on being submitted to a similar manipulation, it was found to be no better than 'cold short iron.'"

From the "Cambrian," 10th Jan., 1857:

"On December 31st the Briton Ferry Iron Company received two of Bessemer's finest ingots of iron to test its value after passing through the rolls. Notwithstanding every care that was bestowed on the process, it was found impossible to do anything with it to the
purpose, and the manager informs us that old rekhit iron, after passing through the same process, is worth by at least £3 per ton more than that tried on this occasion."

At a meeting of the Polytechnic Society at Liverpool, Monday, Sept. 16, 1856, the chairman, Edward Jones Eyre, is reported ("Daily News") to have said that a specimen of Bessemer's iron had been received and tested by Mr. Clay in the presence of Mr. Dawson and himself, and, he regretted to say, had been far from satisfactory; the specimen submitted had all the appearance of burned and imperfect cast-iron. He might say it was rotten hot and rotten cold. Mr. Dawson corroborated this statement, and also said that he had been much disappointed in the result; the portion submitted to the rolling machine had proved in every way intractable. The chairman added, that he hoped ere long better results would be obtained; but in the one to which he referred, he was informed that the cast-iron cost £5 per ton originally, and after being operated on, as he saw it, he did not consider it worth £4 per ton.

Lastly, we find in the "Mining Journal" of January 30, 1857, that the Bessemer process was tried at the works of Moses Jackson, near Glasgow. The usual appearances were noticed, and after about 40 minutes the furnace was tapped, and the purified iron ran white and limpid into moulds prepared for the purpose. After allowing it to cool, it was examined; it had a bright silvery whiteness with large crystals, but was exceedingly brittle. When rolled it preserved the same crystalline appearance on fracture, but in a state of greater compression and without the slightest trace of fibre. It is stated to have been deficient in every quality which would render it valuable for such purposes as malleable iron is usually applied to—in fact, the specimens examined were not malleable, and had nothing of tenacity or ductility, properties which render iron valuable, and are so indispensable for the mechanical requirements of the present age.

Although, therefore, it is scarcely probable that fibrous iron will ever be made from metal that has been subjected to Bessemer's treatment, and although that gentleman was premature in announcing his invention as a thing proved to be practical, we are far from asserting, as some have done, that the time of iron masters has been needlessly occupied in experimenting on the subject, or that no good is likely to accrue to the iron manufacturer from all that has been done and written thereon. The extraordinary tenacity with which iron retains sulphur and phosphorus has been exhibited, and the fact that we must resort to other oxidizing agents than that of air to eliminate them has been demonstrated. The injurious effect of an excessive temperature on the body and quality of iron has been clearly manifested, and the opinions of those whose experience has taught them that it is vain to look for the production of a tough flexible bar from iron which has lost nearly the whole of its carbon, rapidly or without manipulation, has been confirmed. It is more than probable, that iron containing only 0.05 per cent. of carbon, has almost lost the property of becoming fibrous by any treatment; for without going so far as to assert that the development of fibre depends on the presence of carbon, or that carbon exerts a specific action in bringing about this molecular condition of the iron, analysis shows that the toughest and most flexible bar iron contains a far larger quantity of carbon than that above indicated, as will be seen by the following analyses by Gay-Lussac, Willson, Karsten, and Bromels.

Amount of Carbon in Bar Iron.

<table>
<thead>
<tr>
<th>Description</th>
<th>Carbon (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best bar iron from Sweden</td>
<td>0.273</td>
</tr>
<tr>
<td>Bar iron from Creusat</td>
<td>0.250</td>
</tr>
<tr>
<td>Bar iron from Champagne</td>
<td>0.159</td>
</tr>
<tr>
<td>Bar iron from Berry</td>
<td>0.102</td>
</tr>
<tr>
<td>Cold short bar iron from Moselle</td>
<td>0.144</td>
</tr>
<tr>
<td>Soft bar iron analyzed by Karsten</td>
<td>0.200</td>
</tr>
<tr>
<td>Hard bar iron by Karsten</td>
<td>0.300</td>
</tr>
<tr>
<td>Three different varieties produced from white pig iron by the Swabian method of refining, analyzed by Bromels</td>
<td>0.318</td>
</tr>
<tr>
<td>Three different varieties produced from white pig iron by the Swabian method of refining, analyzed by Bromels</td>
<td>0.334</td>
</tr>
<tr>
<td>Three varieties produced from various kinds of pig iron by the Mägdensprung method of refining</td>
<td>0.40</td>
</tr>
<tr>
<td>Three varieties produced from various kinds of pig iron by the Mägdensprung method of refining</td>
<td>0.324</td>
</tr>
<tr>
<td>Three varieties produced from various kinds of pig iron by the Mägdensprung method of refining</td>
<td>0.497</td>
</tr>
<tr>
<td>Three varieties produced from various kinds of pig iron by the Mägdensprung method of refining</td>
<td>0.66</td>
</tr>
</tbody>
</table>

It will be noticed that the smallest amount of carbon indicated in these analyses is nearly three times greater than that found in Bessemerized iron, and in this specimen the
iron is stated to be "cold short," which means deficient in fibre; it is probable that iron retains the last portion of carbon with extraordinary tenacity, and that it can only be made to yield it up by the action of excessive temperature and oxygen; it then passes into a condition of what is called "burnt" iron, which Gmelin states (vol. v. p. 205, English Translation) is the only variety of bar iron that is free from carbon. This is clearly the condition of the ingots made by Bessemer's process; it is stated, however, that by proper management any desired quantity of carbon may be retained, and it remains to be proved how far this will be practicable on the large scale, and whether those varieties of steel and semi-steel alluded to in the patents can really be produced.

Some interesting experiments on fused wrought iron have recently been made by Mr. Riley of the Dowlais Iron Works. By exposing fragments of block plate from the tin works for two hours to the highest heat of a wind furnace, the fragments being covered with cinder from an old assay, a perfectly fused button weighing 1,638 grains, was obtained. When cold, the mass was crystallized and easily broken, the fracture being in the direction of the planes of cleavage of the crystals; one half of the button being worked out into a ¾ inch bar was very soft, with a fine face, and sharp even edges like steel; two pieces when welded, worked well at a welding heat, but on cooling to a red heat became cracky and broke. The fracture of the iron before it had been exposed to welding heat was silky and the body was very tough; it could readily be bent back double without cracking. This experiment was repeated several times, with similar results, the fused buttons being very tough and fibrous when cold, but irremediably craking and breaking to pieces after having been subjected to a welding heat. It would appear, therefore, that fused wrought iron is almost a worthless substance. Mr. Riley is engaged in further experiments, which, it is to be hoped, will throw some light on this singular property of fused wrought iron.

Squeezers are machines which condense a ball by pressure. They are either single or double; their construction will be readily understood from Fig. 362 which represents a single level squeezer of the simplest construction; the bed plate a is cast in one piece; it is 6 feet long, 15 inches wide, and 12 inches high. The whole is screwed down on a solid foundation of stone, brick, or timber; b is the movable part, which makes from 89 to 90 motions per minute. The motion is imparted by the crank c, which in turn is driven by means of a strap and pulley by the elementary power. The diameter of the fly wheel is from 3 to 4 feet. The anvil d is about two feet in length, and from 12 to 14 inches in width; it is a movable plate at least 3 inches thick, which if injured can be replaced by another; the face of the working part of the lever exactly fits the anvil, and consists of plates attached by means of screws. It is desirable to have all these face plates in small parts of 8 or 10 inches in width; by this means they are secured against breaking by expansion and contraction. The whole machine, including the crank and every thing, is made of cast-iron, and weighs from 4 to 5 tons. According to Overman this machine is both cheap and durable, and will squeeze 100 tons of iron per week.

Fig. 363 represents the double squeezer, employed at many English iron works. The drawing is taken from a machine at the Dowlais Iron Works, figured in Mr. Truran's work. Many other forms are in use.

Fig. 364 represents Brown's patent bloom-squeezer. The heated ball of paddled iron x, thrown on the top is gradually pressed between the revolving rollers as it descends, and at last emerges at the bottom, where it is thrown on to a moveable "Jacob's ladder," by which it is elevated to the rolls. This machine effects a considerable saving of time, will do the work of 12 or 14 furnaces, and may be constantly going as a feeder to one or two
pairs of rolls. There are two distinct forms of this machine; in the one figured the bloom receives only two compressions; in another, which is much more effective, it is squeezed four times before it leaves the rolls and falls upon the Jacob’s ladder. Another form of squeezer is shown in fig. 363.

A table a a with a ledge rising up from it to a height of about 2 feet, so as to form an open box, is firmly imbedded in masonry; within this is a revolving box, c, of similar character, much smaller than the last, and placed eccentrically in regard to it. The ball or bloom d is placed between the innermost revolving box c and the outer case a a where the space between them is greatest, and is carried round till it emerges at e, compressed and fit for the rolls.
The re-heating furnace is shown in section in fig. 366; it differs but little from a puddling furnace. The whole interior, with the exception of the hearth, is made of fire-brick; the hearth is made of sand. For this purpose a pure siliceous sand is required; the coarser the better. The hearth slopes considerably towards the flue, the object of which is to keep the hearth dry and hard. The iron wasted in re-heating combines with the silica of the sand, forming a very fusible cinder, which flows off through the opening at b, at which there is a small fire to keep the cinder liquid. The thickness of the sand bottom is from 6 to 12 inches, resting on fire-brick: it generally requires re-making after two or three heats. The height of the fire-brick arch, or its distance from the sand bottom, is from 8 to 12 inches. The area of the fire-place averages 12 feet, and the width of the furnace varies from 5 to 8 feet. When the piles are charged into the furnace, the door is shut, and fine coal is dusted around its edges to exclude the cold air; the temperature is raised to the highest intensity as quickly as possible, and the workman turns the piles over from time to time that they may be brought to a uniform welding heat in the shortest possible time. It is thought by many that a purer iron is obtained by subjecting the hammers as they come out of the puddling furnace to the action of the hammer at first, rather than to the roughing rollers, as by the latter process vitrified specks remain in the metal, which the hammer expels. Hence in some works the hammers are first worked under the forge hammer, and these stampings being afterwards heated in the form of piles or cakes, piled over each other, are passed through the roughing mill.

Bars intended for bottle or tin plates are made from the best cold blast mine iron. The raw pig is refined in the usual manner with coke, the loss amounting to from 2\% to 3\% cwt. per ton. It is then refined a second time with charcoal, the loss amounting again to from 2\% to 3\% cwt. per ton. After this second refining it is beaten into flat plates white hot by the tilting hammer and thrown into cold water; the sudden chilling makes it more easily broken into small slabs. The slabs are piled in heaps and welded in the hollow fire, coke being the fuel; the slabs are laid across the fire, and do not come into contact with the fuel; the blast is thrown under the fuel, and the heat is immense; when the piles are nearly at the fusing point, they are withdrawn and passed under the rollers; they are again heated in the hollow fire, then again rolled and heated a third time in the ordinary reverberatory furnace, after which they are drawn out into flat bars for boiler plates, or for tin plates: the loss in these operations amounts to from 2\% to 4\% cwt. per ton. About 9 baskets are accomplished in 12 hours, each basket consisting of 2\% cwt. of refined metal, and consuming 5 baskets of charcoal.

The bars intended for tin plates are repeatedly heated and rolled until the requisite thinness; the plates are then cut into squares, and annealed by exposing them for several hours to heat in covered iron boxes, being allowed to cool very slowly; this gives the plates the proper degree of pliancy. The next operation is that of pickling; the plates are immersed in dilute sulphuric acid for the purpose of removing from their surfaces all oxide and dirt; after remaining in the acid for the requisite time, they are thoroughly washed in successive troughs of water, and then dried in sawdust; finally, the surfaces of the metal are prepared for the reception of the tin, by rubbing them with leather upon cushions of sheepskin. The spent sulphuric acid is run out into evaporating pans, and the sulphate of iron crystallized out. In order to tin the plates, they are immersed in a bath of melted tin, the surface of which is covered with tallow or palm oil; when sufficiently covered, they are transferred to the brusher on the left-hand side of the tinmer; he passes a rough brush rapidly over each side of the plate, whereby the superfluous tin is removed; he then ploughs the plate again through the tin bath, and passes it on to his left-hand neighbor, who gives it a washing. The plate passes through several hands before it is dried. Great skill is required in the tinning process; nevertheless in a well-conducted work the wasters do not amount to more than 10 per cent.; a small percentage of which are so bad as to require to be reworked. Great care is taken to avoid waste, tin being worth 150\% per ton. A box of 225 sheets of tin plates, 10 inches by 14, consumes about 8\% lbs. of tin. See Tin Plate.

Dry assay of iron ores.—The object of a dry assay of an iron ore is to ascertain by an experiment on a small scale the amount of iron which the ore should yield when smelted on the large scale in the blast furnace. For this purpose, the metal must be deoxidized, and such a temperature produced as to melt the metal and the earths associated with it in the ore, so that the former may be obtained in a dense button at the bottom of the crucible, and the latter in a lighter glass or slag above it. Such a temperature can only be obtained in a wind furnace connected with a chimney at least 30 feet in height, and when made expressly for assaying the furnace, is generally built of such a size that four assays may be made at the same time, viz. about 14 inches square, and 2 feet in depth from the under side of the cover to the movable bars of iron which form the grate. In order that the substances associated with the iron in the ore should form a fusible compound, it is usually requisite to add a flux, the nature of which will depend upon the character of the ore and the expected products. Berthier divides iron ores into five classes: 1. The almost pure oxides, such as the magnetic oxide, dolostic iron, and the haematites; 2. Ores containing silica, but free or
nearly so from any other admixture; 3. Ores containing silica and various bases, but little or no lime; 4. Ores containing one or more bases, such as lime, magnesia, alumina, oxide of manganese, oxide of titanium, oxide of tantalum, oxide of chromium, or oxide of tungsten, but little or no silica; 5. Ores containing silica, lime, and another base, and which are fusible alone. Ores of the first class may be reduced without any flux, but it is always better to employ one, as it greatly facilitates the formation of the button; borax may be used, or, better, a fusible earthy silicate, such as ordinary flint glass. Ores of the second class require some base to serve as a flux, such as carbonate of soda, a mixture of carbonate of lime and clay, or of carbonate of lime and dolomite; ores of the third class are mixed with carbonate of lime in the proportion of from one-half to three-fourths of the weight of the foreign matter present in the ore. Ores of the fourth class require as a flux silica in the form of pounded quartz, and generally also some lime; the manganese spathic ores which belong to this class may be assayed with the addition of silica alone, but the magnesian spathic ores require lime. Ores of the fifth class require no flux.

Method of conducting the assay.—One hundred grains of the ore finely pulverized and passed through a silk sieve are well mixed with the flux, and the mixture introduced into the smooth concavity made in the centre of a crucible that has been lined with charcoal; the lining of the crucible is effected by partially filling it with coarsely powdered and slightly damped charcoal or brosque, which is then rammed into a solid form by the use of a light wooden pestle. The mingled ore and flux must be covered with charcoal. The crucible thus filled is closed with an earthen lid hinged on with fire clay; and it is then set on its base in the air furnace. The heat should be very slowly raised, the damper remaining closed during the first half-hour. In this way, the water of the damp charcoal evaporates slowly, and the decarbonation of the ore is completed before the fusion begins; if the heat were too high at first, the luting would probably split, and moreover, the slag formed would dissolve some oxide of iron, which would be lost to the button, and thus give an erroneous result. After half an hour, the damper is gradually opened, and the furnace being filled with fresh coke, the temperature is raised progressively to a white heat, at which pitch it must be maintained for a quarter of an hour; the damper is then closed and the furnace is allowed to cool. As soon as the temperature is sufficiently reduced, the crucible is removed and opened over a sheet of brown paper; the brosque is carefully removed, and the button of cast-iron taken out and weighed. If the experiment has been entirely successful, the iron will be found at the bottom of the crucible in a small round button, and the slag will be entirely free from any adhering metallic globules, and will resemble in appearance ground bottle glass; should, however, the slag contain small metallic particles, the experiment is not necessarily a failure, as they may generally be recovered by washing and the magnet. But if, on breaking the crucible, the reduced metal should be found in a partially melted state, and not collected into a distinct mass, it indicates either too low a temperature or an improper selection of fluxes, and the experiment must be repeated. The iron obtained is not chemically pure, but contains carbon, and if the ore is manganiferous, manganese; the result is therefore somewhat too high, though indicating with sufficient exactness for all manufacturing purposes, the richness of the ore assayed.

Blind assay of iron ores.—The quantitative determination of the various substances that occur in iron ores, demands on the part of the operator a considerable amount of skill and patience, and can only be profitably undertaken by those who have acquired in the laboratory a thorough acquaintance with analytical operations. As, however, much attention has of late years been bestowed on the composition of iron ores, and as certain elements, viz. manganese, sulphur, and phosphorus, are frequently present, which very considerably affect their commercial value, we deem it right to give a detailed account of the operations to be performed in order to arrive at an accurate knowledge of the composition of an ore.

Taking for illustration a specimen of the most complicated composition, the substances besides iron to be looked for, and estimated, are water, (hypersosopic and combined), organic matter, sulphur, (as sulphuric acid, and as bisulphide of iron), phosphoric acid, carbonic acid, silicious acid, oxide of manganese, alumina, lime, and alkaloids; lead, tin, copper, and arsenic are also occasionally met with; these metals are sought for when a suspicion of their presence is entertained by a special operation on a large quantity of ore.

Too great care cannot be bestowed on the sampling of ores intended for analysis; to expend so much time and labor on an isolated specimen (unless for a special object) is worse than useless; the sample operated upon should be selected from a large heap, which should be thoroughly gone over, and several dozen pieces taken from different parts; these should be coarsely powdered and mixed, and about half a pound taken from the mass should be preserved in a well-corked bottle for examination.

1. Determination of water, (hypersosopic and combined).—About 50 grains of the ore are dried in the water oven till no further loss of weight is experienced; the loss indicates the hydrosopic water; the residue is introduced into a tube of hard glass, to which is adapted a weighed tube containing chloride of calcium; the powder is then gradually raised to a
low red heat, the combined water is thereby expelled, and its amount determined by the
increase in weight of the chloride of calcium tube. Some ores (the hydrated hematites)
contain as much as 12 per cent. of combined water.

2. Sulphuric acid and sulphur.—From 30 to 50 grains of the ore are digested with
hydrochloric acid, filtered and washed. The filtrate, concentrated if necessary by evapora-
tion, is precipitated by great excess of chloride of baryum. Every 100 parts of the sulphate
of baryta produced, indicate 34.37 parts of sulphuric acid. The insoluble residue on the
filter is fused in a gold crucible with nitre and carbonate of soda, the fused mass is dis-
solved in hydrochloric acid, evaporated to dryness, moistened with strong acid, diluted
and filtered; from the filtrate the sulphuric acid is precipitated as sulphate of baryta,
every 100 parts of which indicate 15.748 parts of sulphur, and 25.48 parts of bisulphate
of iron.

In the analysis of hematites it is necessary to bear in mind, that perchloride of iron
is partially reduced when boiled with finely divided iron pyrites and hydrochloric acid, sul-
phuric acid being formed.—Dick.

Phosphoric acid.—From 30 to 75 grains of the ore are digested with hydrochloric acid
and filtered; the clear solution, which should not be too acid, is boiled with sulphate of
ammonia, added gradually in small quantities till it either becomes colorless, or acquires a
pale green color, indicating that the peroxide of iron originally present has been reduced
to protoxide; the solution is nearly neutralized with carbonate of ammonia, excess of
acetate of ammonia added, and the liquid boiled; strong solution of perchloride of iron is
then added drop by drop, until the precipitate which forms has a distinct red color; this
precipitate, which contains all the phosphoric acid originally present in the ore, is collected
on a filter, washed, and redissolved in hydrochloric acid, tartaric acid added, and then am-
monia. From this ammoniacal solution, the phosphoric acid is finally precipitated as am-
monio-phosphate of magnesium, by the addition of chloride of ammonium, sulphate of mag-
nesia, and ammonia. The precipitate is allowed 24 hours to subside, it is then collected on
a filter, and if it has a yellow color, which is almost invariably the case, it is dissolved in
hydrochloric acid, and more tartaric acid being added, it is again precipitated by ammno-
nia: 100 parts of the ignited pyrophosphate of magnesia correspond to 94.3 parts of phos-
phoric acid.

Alkalies.—It was ascertained by Mr. Dick, that nearly the whole of the alkali present
in an iron ore is contained in that portion which is insoluble in hydrochloric acid.
The residue from about 50 grains of the ore is placed in a platinum capsule, moistened
with ammonia, and exposed for several hours to the action of hydrochloric acid gas in
a closed leaden dish; it may be necessary to repeat the operation if much silica is pres-
cent; it is then slowly heated to dull redness, and dissolved in dilute hydrochloric acid;
the solution is mixed with excess of baryta water and filtered; the excess of baryta is re-
moved by carbonate of ammonia, and the solution is evaporated to dryness and ignited;
the residue is redissolved in a little hot water, and a few drops of oxalate of ammonia added.
If no precipitate or cloudiness occurs, it may be once more evaporated to dryness and gently
ignited; the residue is chloride of potassium, 100 parts of which indicate 63 parts of potash.
Should oxalate of ammonia have occasioned a precipitate, it must be filtered off, and the
clear liquid evaporated. The search for potash is troublesome and lengthy; it may be al-
gether omitted in a technical analysis.

Determination of the remaining constituents.—25 or 30 grains of the finely powdered
ore are digested for about half an hour with strong hydrochloric acid, diluted with boiling
distilled water and filtered. The residue on the filter being thoroughly washed, the solution
is peroxized, if necessary, by the addition of chlorate of potash, nearly neutralized by
ammonia, boiled with excess of acetate of ammonia, and rapidly filtered while hot; the
filtrate, (which should be colorless) together with the washings, is received in a flask,
ammonia is added, and then a few drops of bromine, and the flask closed with a cork.
In a few minutes, if manganese be present, the liquid acquires a dark color; it is allowed
to remain at rest for 24 hours, then warmed, and rapidly filtered and washed; the brown
substance on the filter is hydrated oxide of manganese: it loses its water by ignition, and
then becomes MnO, 100 parts of which correspond to 93 parts of protoxide.

The liquid filtered from the manganese contains the lime and magnesia; the former is
precipitated by oxalate of ammonia, and the oxalate of lime formed converted by ignition
into carbonate, in which state it is either weighed, having been previously evaporated with
carbonate of ammonia, or it is converted into sulphate by the addition of a few drops of
sulphuric acid, evaporation, and ignition. The lime being separated, the magnesia is thrown
down as ammonio-magnesian phosphate by phosphate of soda and ammonia, and after stand-
ning for 24 hours it is collected on a filter, washed with cold ammonia water, dried, ignited,
and weighed; 100 parts of carbonate of lime correspond to 56.9 of lime; 100 parts of
sulphate of lime to 40.1 of lime, and 100 parts of pyrophosphate of magnesia to 35.7 of
magnesia.

The red precipitate collected on the filter after the boiling with acetate of ammonia,
consists of the basic acetates of iron and alumina, together with the phosphoric acid. It is dissolved in a small quantity of hydrochloric acid, and then boiled in a silver or platinum basin with considerable excess of pure caustic potash; the alumina (with the phosphoric acid) is hereby dissolved, the insoluble portion, is allowed to subside, and the clear liquid is then decanted. After which the residue is thrown on a filter and washed; the filtrate and washings are supersaturated with hydrochloric acid, nearly neutralized with ammonia, and the alumina finally precipitated by carbonate of ammonia. From the weight of the ignited precipitate, the corresponding amount of phosphoric acid determined by a separate operation is to be deducted, the remainder is calculated as alumina. The residue left after digesting the ore with hydrochloric acid, consists principally of silicates, but it may also contain alumina, peroxide of iron, lime, magnesia, and potash. For practical purposes it is rarely necessary to submit it to minute examination; should such be desired, it must be dried, ignited, and weighed. Then fused in a platinum crucible with four times its weight of mixed alkaline carbonates, the fused mass dissolved in dilute hydrochloric acid, and evaporated to dryness, the residue resoluted with strong hydrochloric acid, and after standing at rest for some hours, digested with hot water, filtered, and the silicate on the filter ignited and weighed. The alumina, lime, oxide of iron, and magnesia in the filtrate are separated from each other according to the instructions given above; the potash is estimated by a distinct process.

Carbo nic acid.—This acid, which constitutes a considerable part of the weight of that large and important class of ores the clay ironstones, is estimated by noting the loss sustained after adding to a weighed portion of the ore sulphuric acid, and thus evolving the gas; or more roughly, by the loss sustained in the entire analysis. Another method is to fuse 20 or 25 grains of the ore with 60 or 80 grains of dry borax, and noting the loss, which consists of water and carbonic acid; by deducting the water obtained in a previous experiment, the quantity of carbonic acid is obtained. This method, however, can scarcely be recommended, on account of the corrosion of the crucible, though the results are very accurate.

Determination of the iron.—This is performed on a separate portion of the ore, either by the volumetric method of Marguerite, or by that of Dr. Penny: both give very exact results. Marguerite's method is based on the reciprocal action of the salts of protoxide of iron and permanganate of potash, whereby a quantity of the latter is decomposed exactly proportionate to the quantity of iron. The ore (about 10 or 15 grains) is dissolved in hydrochloric acid, and the metal brought to the minimum of oxidation by treating the solution with sulphite of soda, (or better, sulphite of ammonia) and boiling to expel the excess of sulphurous acid; the solution of permanganate of potash is then cautiously added drop by drop, until the pink color appears, and the number of divisions of the burette required for the purpose accurately noted. The solution should be considerably diluted, and there must be a sufficient quantity of free acid present to keep in solution the peroxide of iron formed and also the oxide of manganese. The whole of the iron must be at the minimum of oxidation, and the excess of sulphuric acid must be completely expelled; if the latter precaution be neglected, an erroneous result will be obtained, as the sulphuric acid will itself take oxygen from the permanganic acid, and thus react in the same manner as iron.

To prepare the permanganate of potash, 7 parts of chlorate of potassium, 10 parts of hydrate of potassa, and 8 parts of peroxide of manganese are intimately mixed. The manganese must be in the finest possible powder, and the potash having been dissolved in water, is mixed with the other substances, dried, and the whole heated to very dull redness for an hour. The fused mass is digested with water, so as to obtain as concentrated a solution as possible, and diluted nitric acid added till the color becomes of a beautiful violet; it is afterwards filtered through asbestos. The solution must be defended from the contact of organic matter, and kept in a glass stoppered bottle. If the solution be evaporated, it yields beautiful red acicular crystals: it is better to employ the crystals in the preparation of the test liquor, as the solution keeps much better when no manganese is present. To prepare the normal or test liquor, a certain quantity, say 15 grms. of planio-fopte wire is dissolved in pure hydrochloric acid; after the disengagement of hydrogen has ceased, and the solution is complete, the liquor is diluted with about a pint of water, and accurately divided by measurement into two equal parts, the number of burette divisions of the solution of permanganate required to produce in each the pink color is accurately noted; and this number is then employed to reduce into weight the result of the analysis of an ore. A useful normal liquor is made by dissolving 100 grains of the crystallized permanganate in 10,000 grains of water.

Penny's method is based on the reciprocal action of chromic acid and protoxide of iron, whereby a transference of oxygen takes place, the protoxide of iron becoming converted into peroxide, and the chromic acid into sesquioxide of chromium. The process is conducted as follows: A convenient quantity of the specimen is reduced to coarse powder, and one-half at least of this is still further pulverized until it is no longer gritty between the fingers. The test solution of bichromate of potash is next prepared: 44.4 grains of this
salt in fine powder are weighed out, and put into a burette graduated into 100 equal parts, and warm distilled water is afterwards poured in until the instrument is filled to $\frac{1}{2}$. The pan of the hand is then securely placed on the top, and the contents agitated by repeatedly inverting the instrument until the salt is dissolved and the solution rendered of uniform density throughout. Each division of the solution thus prepared contains 0.444 grains of bichromate, which Dr. Penny ascertained to correspond to a grain of metallic iron. The bichromate must be pure, and should be thoroughly dried by being heated to incipient fusion. 100 grains of the converted iron-stone are now introduced into a Florence flask, with 13 oz. by measure of strong hydrochloric acid and $\frac{1}{2}$ oz. of distilled water. Heat is cautiously applied, and the mixture occasionally agitated until the effervescence caused by the escape of carbonic acid ceases; the heat is then increased, and the mixture made to boil, and kept at moderate ebullition for ten minutes or a quarter of an hour. About 6 oz. of water are next added and mixed with the contents of the flask, and the whole filtered into an evaporating basin. The flask is rinsed several times with water, to remove all adhering solution, and the residue on the filter is well washed. Several small portions of a weak solution of red prussiate of potash (containing 1 part of salt to 40 water) are now dropped upon a white porcelain slab, which is conveniently placed for testing the solution in the basin during the next operation. The prepared solution of bichromate of potash in the burette is then added very cautiously to the solution of iron, which must be repeatedly stirred, and when as dark a greenish shade it should be occasionally tested with the red prussiate of potash. This may be easily done by taking out a small quantity on the end of a glass rod, and mixing it with a drop of the solution on the porcelain slab. When it is noticed that the last drop communicates a distinct blue tinge, the operation is terminated; the burette is allowed to drain for a few minutes, and the number of divisions of the test liquor consumed read off. This number multiplied by 2 gives the amount of iron per cent. The necessary calculation for ascertaining the corresponding quantity of protoxide is obvious. If the specimen should contain iron in the form of peroxide, the hydrochloric solution is deoxidized as before by sulphite of ammonia. The presence of protoxide of iron in an ore is easily detected by dissolving 30 or 40 grains in hydrochloric acid, diluting with water, and testing a portion of the solution with sulphocyanide of potash. If a decided blood-red color is produced, protoxide of iron is present. If it be desired to ascertain the relative proportions of peroxide and protoxide of iron in an ore, two operations must be performed: one on a quantity of the ore that has been dissolved in hydrochloric acid in a stout stoppered bottle; and another on a second quantity that has been dissolved as usual, and then deoxidized by sulphite of ammonia or of metallic zinc. It is advisable to employ the solution of bichromate much weaker than proposed by Dr. Penny, and to employ a burette graduated to cubic millimetres. A good strength is 1 grain of metallic iron = 10 cubic centimetres of bichromate.

**Metals precipitable by sulphurated hydrogen from the hydrochloric solution.**—A weighed portion of the ore varying from 200 to 2,000 grains is digested for a considerable time in hydrochloric acid; the solution is filtered off; the iron in the filtrate reduced when necessary by sulphite of ammonia, and a current of sulphurated hydrogen passed through it. A small quantity of sulphur which is always suspended is collected on a filter and thoroughly washed; it is then incoerced at as low a temperature as possible. The residue (if any) is mixed with carbonate of soda and heated upon charcoal before the blowpipe; any globules of metal that may be obtained are dissolved and tested.

**Analysis of pig iron.**—The most important constituents to be determined are carbon, (combined and uncombined,) silicon, sulphur, phosphorus; those of less consequence, or of more rare occurrence, are manganese, arsenic, copper, zinc, chromium, titanium, cobalt, nickel, tin, aluminium, calcium, magnesium, and the metals of the alkalies.

1. **Determination of the total amount of carbon.**—About 100 grains of the iron in small pieces are digested, at a moderate temperature, in 6-oz. measures of a solution formed by dissolving 6 oz. of crystallized sulphate of copper, and 3 oz. of common salt in 20 oz. of water and 2 oz. of concentrated hydrochloric acid. The action is allowed to proceed until all, or nearly all the iron is dissolved. Carbon and copper are left insoluble; these are collected on a filter, and washed first with dilute hydrochloric acid, (to prevent the precipitation of subchloride of copper,) then with water, then with dilute caustic potash, and finally with boiling water. The mixed carbon and copper are dried on the filter, from which they are easily removed by a knife-blade, and are mixed with oxide of copper, and burned in a combustion tube in the usual way, with a current of air, or, still better, of oxygen. The carbonic acid is collected in Liebig's apparatus, from which the amount of carbon is calculated.

2. **Graphite, or uncombined carbon.**—A weighed portion of the finely divided iron (filings or borings may be used) is digested with moderately strong hydrochloric acid; the combined carbon is evolved in combination with hydrogen, while the graphite is left undissolved. It is collected on a filter, washed, and then boiled with a solution of caustic potash, sp. gr. 1.27, in a silver dish; the silica which existed in the iron in the form of...
silicon is hereby dissolved; the clear caustic solution is drawn off by a pipe or syphon, and the black residue repeatedly washed; it is dried at as high a temperature as it will bear, and weighed; it is then heated to redness in a current of air, until the whole of the carbon is burnt off. A reddish residue generally remains, which is weighed, and the weight deducted from that of original black residue; the difference gives the amount of graphite.

3. Silicon.—The amount of this element is determined by evaporating to dryness a hydrochloric solution of a weighed quantity of the metal: the dry residue is digested with hydrochloric acid, diluted with water, boiled and filtered; the insoluble matter on the filter is washed, dried, and ignited, until the whole of the carbon is boiled off; it is then weighed, after which it is digested with solution of potash, and the residue, if any, washed, dried, ignited, and weighed; the difference between the two weights gives the amount of silicic acid, 100 parts of which indicate 47 parts of silicon.

Phosphorus.—A weighed portion of the metal is digested in nitro-hydrochloric acid, evaporated to dryness, and the residue digested with hydrochloric acid. The solution is treated precisely as recommended for the determination of phosphoric acid in ores; every 100 parts of pyrophosphate of magnesia indicate 29.55 parts of phosphorus.

Sulphur.—In gray iron this element is very conveniently and accurately estimated by allowing the gas evolved by the action of hydrochloric acid on a weighed quantity (about 100 grains) of the metal, in flues or borings, to pass slowly through a solution of acetate of lead acidified by acetic acid: the sulphur, the whole of which takes the form of sulphuric monosulphide, enters into combination with the lead, forming a black precipitate of sulphide of lead, which is collected, washed, and converted into sulphate of lead by digesting it with nitric acid, evaporating to dryness, and gently igniting: 100 parts sulphate of lead = 10.55 sulphur. The most minute quantity of sulphur in iron is detected by this process. If, however, crude white iron is under examination, this method does not give satisfactory results, on account of the difficulty with which it is acted upon by hydrochloric acid; it is better, therefore, to treat the metal with nitro-hydrochloric acid, evaporated to dryness, redigest with hydrochloric acid, and then precipitate the filtered solution with great excess of chloride of barium; or the finely divided metal may be fused in a gold crucible with an equal weight of pure nitrate of soda and twice its weight of pure alkaline carbonates; the fused mass is extracted with water acidified with hydrochloric acid, and finely precipitated by chloride of barium.

Arsenic and copper.—The nitro-hydrochloric solution of the metal is evaporated to dryness, redigested with hydrochloric acid, and filtered. The iron in the clear solution is reduced to protocopper by boiling with a sufficient quantity of sulphite of ammonia, the solution is boiled till it has lost all smell of sulphurous acid. It is then saturated with sulphurized hydrogen, and allowed to stand for 24 hours in a closed vessel, the excess of gas is boiled off, and the precipitate, if any, collected on a small filter and well washed; it is digested with monosulphide of potassium, which dissolves the sulphide of arsenic, leaving the sulphide of copper untouched; the latter is decomposed by heating with nitric acid, and the presence of copper evinced by the addition of ammonia, which produces a fine blue color; the sulphide of arsenic is precipitated from its solution in sulphide of potassium by dilute sulphuric acid; it may be redissolved in aqua regia, and the nitric acid having been expelled by evaporation, the arsenic may be reduced in Marsh’s apparatus.

Nickel and cobalt.—These metals, if present, will be found in the solution from which the copper and arsenic have been precipitated by sulphurized hydrogen. The solution is peroxidized, and the sesquisoxide of iron precipitated by slight excess of carbonate of baryta, after which the nickel and cobalt are precipitated by sulphide of ammonium.

Chromium and vanadium.—These metals, which should be looked for in the carbonaceous residue obtained by dissolving a large quantity of the iron in dilute hydrochloric or sulphuric acid, are detected as follows (Whitby).—The ignited residue is intimately mixed with one-third of its weight of nitre, and exposed for an hour in a crucible to a gentle ignition. When cool, the mass is powdered and boiled with water. The filtered solution is gradually mixed and well stirred with nitric acid, taking care that it may still remain slightly alkaline, and that no nitrous acid is liberated which would reduce the vanadic and chronic acids. The solution is then mixed with an excess of solution of chloride of barium as long as any precipitate is produced. The precipitate, which consists of vanadate and chromate of baryta, is decomposed with slight excess of dilute sulphuric acid, and filtered. The filtrate is neutralized with ammonia, concentrated by evaporation, and a fragment of chloride of ammonium placed in it. In proportion as the solution becomes saturated with chloride of ammonium, vanadate of ammonium is deposited as a white or yellow crystalline powder. To test for chromium only, the mass after fusion with nitre is extracted with water, and then boiled with carbonate of
ammonia; the solution is neutralized with acetic acid, and then acetate of lead added; the
production of a yellow precipitate indicates chronic acid.
Aluminium.—This metal is best separated from iron by first reducing the latter to the
state of protoxide by sulphite of ammonia, then neutralizing with carbonate of soda,
and afterwards boiling with excess of caustic potash until the precipitate is black and
pulverulent. The solution is then filtered off, slightly acidulated with hydrochloric acid,
and the alumina precipitated by sulphide of ammonia.
Calcium and magnesium.—These metals are found in the solution from which the iron
and aluminium have been separated; they both exist probably (together with the
aluminium) in the cast iron in the form of slag, and are best detected in the black residue
which is left on dissolving the iron in dilute sulphuric or hydrochloric acid. After
digesting this residue with caustic potash, and burning away the graphite, a small
quantity of a red powder is left, which is composed of silice acid, oxide of iron, alumina,
lime, and magnesia; if 500 grains of cast iron are operated upon, a sufficient quantity
of insoluble residue will be obtained for a qualitative determination of its constituents.

IVORY, FICTILE.

It is not our intention to enter into the consideration of the handicrafts em-
ploying ivory, but a short account of the methods of preparing this beautiful material,
which we extract from Holtschpflg's Mechanical Manipulations, will be of value.

On account of the great value of ivory, it requires considerable judgment to be em-
ploved in its preparation, from three conditions observable in the form of the tusk: first,
its being curved in the direction of its length; secondly, hollow for about half that extent,
and gradually taper from the solid state to the thin feather edge at the root; and thirdly,
elliptic or irregular in section. These three peculiarities give rise to as many separate
considerations in cutting up the tooth with the requisite economy, as the only waste should be
that arising from the passage of the thin blade of the saw; even the outside strips of the
rind, called spils, are employed for the handles of penknives, and many other little
objects; the scraps are burned in retorts for the manufacture of ivory black, employed for
making ink for copperplate printers, and other uses; and the clean sawdust and shavings
are sometimes used for making jelly.

The methods of dividing the tooth, either into rectangular pieces or those of a circular
figure required for turning, are alike in their early stages, until the lathe is resorted to.
The ivory saw is stretched in a steel frame to keep it very tense; the blade generally measures
from fifteen to thirty inches long, from one and a half to three inches wide, and about
the fortieth of an inch thick; the teeth are rather coarse, namely, about five or six to the
inch, and they are sloped a little forward, that is, between the angle of the common hand-
saw tooth and the cross-cut saw. The instrument should be very sharp, and but slightly
set; it requires to be guided very correctly in entering, and with no more pressure than
the weight of its own frame, and is commonly lubricated with a little lard, tallow, or other
solid fat.

The cutter begins generally at the hollow, and having fixed that extremity parallel
with the vice, with the curvature upwards, he saws off that piece which is too thin for
his purpose, and then two or three parallel pieces to the lengths of some particular works,
for which the thickness of the tooth at that part is the most suitable: he will then saw off
one very wedge-form piece, and afterwards two or three more parallel blocks.

In setting out the length of every section, he is guided by the gradually increasing
thickness of the tooth; having before him the patterns or images of his various works, he
will in all cases employ the hollow for the thickest work it will make. As the tooth ap-
proaches the solid form, the consideration upon this score gradually ceases, and then the
blocks are cut off to any required measure, with only a general reference to the distribution
of the heel, or the excess arising from the curved nature of the tooth, the cuts being in
general directed as nearly as may be to the imaginary centre of curvature. The greater
waste occurs in cutting up very long pieces, owing to the difference between the straight
line and the curve of the tooth, on which account the blocks are rarely cut more than five
or six inches long, unless for some specific object."

IVORY, FICTILE, is plaster of Paris which has been made to absorb, after drying,
melted spermaceti, by capillary action, or it may be prepared according to Mr. Franchi's
process as follows: Plaster and coloring matter are employed in the proportions of a
pound of superfine plaster of Paris to half an ounce of Italian yellow ocher. They are
intimately mixed by passing them through a fine silk sieve, and a plaster cast is made
in the usual way. It is first allowed to dry in the open air, and is then carefully heated in an
oven; the plaster cast, when thoroughly dry, is soaked for a quarter of an hour in a bath
containing equal parts of white wax, spermaceti, and stearine, heated just a little beyond
the melting point. The cast on removal is set on edge, that the superfusuous composition
may drain off, and before it cools, the surface is brushed, with a brush like that known by
house painters as a sash tool, to remove any wax which may have settled in the crevices;
and finally when the plaster is quite cold, its surface is polished by rubbing it with a tuff
of cotton wool.
JAPANNING is a kind of varnishing or lacquering, practised with excellence by the Japanese, whence the name.

The only difference between varnishing and japanning is that after the application of every coat of color or varnish, the object so varnished is placed in an oven or stove at as high a temperature as can safely be employed without injuring the articles or causing the varnish to blister or run.

For black japanned works, the ground is first prepared with a coating of black, made by mixing dress ivory black with a proper consistence with dark-colored animal varnish, as this gives a blacker surface than could be produced by Japan alone. If the surface is required to be polished, five or six coats of Japan are necessary to give sufficient body to prevent the Japan from being rubbed through in polishing.

Colored japans are made by mixing with some hard varnishes the required color, and proceeding as described. See Varnish, vol. ii.

JET. (Jet, or Jais, Fr.) Jet occurs in the upper lias slate in the neighborhood of Whitby, in Yorkshire, in which locality this very beautiful substance has been worked for many hundreds years. The jet miner searches with great care the shaly rocks, and finding the jet spread out, often in extreme thinness between the laminations of the rock, he follows it with great care, and frequently he is rewarded by its thickening out to two or three inches.

The best jet is obtained from a lower bed of the upper lias formations. This bed has an average thickness of about 20 feet, and is known as jet rock. An inferior kind, known as soft jet, is obtained from the upper part of the upper lias, and from the sandstone and shale above it. The production of jet in this country appears to be limited to the coast of Yorkshire, from about nine miles south of Whitby to Boulby, about the same distance to the north; the estates of Lord Mulgrave being especially productive. There is a curious allusion to this in Drayton's Polyolbion:

The rocks by Moultgrave, too, my glories forth to set,
Out of their crummed rocks can give you perfect jet.

Dr. Young, in his Geology of the Yorkshire Coast, writes:—"Jet, which occurs here in considerable quantities in the aluminous bed, may be properly classed with fossil wood, as it appears to be wood in a high state of bitumenization. Pieces of wood impregnated with silex are often found completely covered with a coat of jet about an inch thick. But the most common form in which the jet occurs is in compact masses of from half an inch to two inches thick, from three to eighteen inches broad, and of ten or twelve feet long. The outer surface is always marked with longitudinal striæ, like the grain of wood, and the transverse fracture, which is conchoidal, and has a resinosus lustre, displays the annual growth in compressed elliptical zones. Many have supposed this substance to be indurated petrolea, or animal pitch; but the facts now quoted are sufficient to prove its ligneous origin."

It does not appear to us that the "ligneous origin" of jet is by any means established; indeed we think the amount of evidence is against it. There is no example, as far as we can learn, of any discovery of true jet having a strictly ligneous structure, or showing any thing like the conversion of wood into this coal-like substance. There appears, however, to have been some confusion in the observations of those who have written on the subject. Mr. Simpson, the intelligent curator of the Whitby museum, who has paid much attention to the subject, says:—"Jet is generally considered to have been wood, and in many cases it undoubtably has been so; for the woody structure often remains, and it is not unlikely that comminuted vegetable matter may have been changed into jet. But it is evident that vegetable matter is not an essential part of jet, for we frequently find that bone, and the scales of fishes also have been changed into jet. In the Whitby museum there is a large mass of bone, which has the exterior converted into jet for about a quarter of an inch in thickness. The jetty matter appears to have first entered the pores of the bone, and there to have hardened; and during the mineralizing process, the whole bony matter has been gradually displaced, and its place occupied by jet, so as to preserve its original form." After an attentive examination of this specimen, we are not disposed to agree entirely with Mr. Simpson.

Jet certainly incrusts a mass which has something the structure of a bone, but, without a chemical examination of its constituents, we should hesitate even to say it was bone. Wood without doubt has been found encrusted with jet, as fragments of animal matter may also have been. But it is quite inconsistent with our knowledge of physical and chemical changes, to suppose that both animal and vegetable matter would undergo this change. By process of substitution, we know that silica will take the place occupied by carbon, or woody matter; as, for example, in the fossil palms of Trinidad, and the silicified forests of
KATTIMUNDOO OR CUTTEMUNDOO.

Egypt; but we have no example within the entire range of the coal formations of the world of carbon taking the place of any of the earths. Its is found in plates, which are sometimes penetrated by belemnites. Mr. Ripley, of Whitby, has several curious examples: two plates of jet, in one case cloison water-worn quartz pebbles; and in another jet partially invades an angular fragment of quartz rock. This is the more remarkable," says Mr. Simpson, "as quartz rock, or, indeed, any other sort of rocky fragment, is rarely found in the upper lias.

The fact that we find jet surrounding belemnites, ease adventitious masses of stone, and investing wood, seems to show that a liquid, or at all events a plastic condition, must at one time have prevailed. We have existing evidence of this. Dr. Young, in his work already quoted, says:—"In the cavities of nodules containing petrifactions, we sometimes meet with petroleum, or mineral oil. When first exposed, it is generally quite fluid, and of a dark green color; but it soon becomes viscid and black, and at last hardens into a kind of pitch, which generally melts with heat, and when ignited burns with a crackling noise, and emits a strong bituminous smell." One more sample of evidence in favor of the view that jet has been formed from wood. It is stated (Reed's Illustrated Guide to Whitby) that in front of the cliffwork of Haitham Wyke existed a petrified stump of a tree, in an erect posture, three feet high, and fifteen inches across, having the roots of the jet in a bed of shale; whilst the trunk in the sandstone was partly petrified, and partly of decayed sooty wood. Even in this example it would appear that, after all, a coating of jet was all that really existed upon this example of the equisetum, which probably stands where it grew. Mr. Simpson, in a valuable little publication, "The Fossils of the Yorkshire Lias described from Nature, with a Short Outline of the Geology of the Yorkshire Coast," says:—"From all we know respecting this beautiful mineral, it appears exceedingly probable that it has its origin in a certain bituminous matter, or petroleum, which abundantly impregnates the jet-rock; giving out a strong odor when it is exposed to the air. It is frequently found in a liquid state in the chambers of ammonites and belemnites and other cavities, and, whilst the maniples of the operator is breaking a jet nodule, it flies out and stains his garment. This petroleum, or mineral oil, also occurs in nodules which contain no organic remains; and I have been informed by an experienced jet miner that such nodules are often associated with a good seam of jet, and are therefore regarded as an omen of success."

Jet is supposed to have been worked in this country long before the time of the Danes in England, for the Romans certainly needed jet for ornamental purposes. Lionel Charlton, in the history of Whitby, says that he found the ear-rings of a lady, having the form of a heart, with a hole in the upper end for suspension from the ear; it was found in one of the Roman tumuli, lying close to the jaw bone. There exists no doubt that when the abbey of Whitby was the seat of learning and the resort of pilgrims, jet rosaries and crosses were common. The manufacture was carried on till the time of Elizabeth, when it seems to have ceased suddenly, and was not resumed till the year 1800, when Robert Jefferson, a painter, and John Carter made beads and crosses with files and knives—a neck-gird, made in this manner, fetched one guinea. A stranger coming to Whitby saw them working in this rude way, and advised them to try to turn it; they followed his advice and found it answer; several more then joined them, and the trade has been gradually increasing since. Most of the jet ornaments are sent to London, the inferior ones are mostly purchased for the American market.

The jet workers complain of the great scarcity of designs in jet. Several designs have been sent them, but the artists not being acquainted with the peculiarities of the material, their designs are not generally applicable, and the manufacturer is much more successful in the imitation of natural objects than any artificial combination.

KALEIDOPHON. An instrument devised by Prof. Wheatstone. An elastic thin bar is fixed by one of its extremities, and at its free end it carries a silvered or polished ball; a ray of light is reflected from this ball, and when the thin plate is put in vibration, the fine point of light describes various curves, corresponding with the musical notes produced by the vibrations.

KARN. A Cornish miner's term, frequently, according to Borida, used to signify the solid rock; more commonly a pile of rocks.

KARSTENITE. The name given by Huma to anhydrous sulphate of lime.

KATTIMUNDOO OR CUTTEMUNDOO. A caoutchouc-like substance obtained from the Euphorbia antiquorum of Roxburgh. It was first exhibited in this country in the Great Exhibition of 1851, being sent by Mr. W. Elliott from Vizagapatam. It was of a dark brown color, opaque except in thin pieces, hard and somewhat brittle at common temperatures, but easily softened by heat. Perfectly insoluble in boiling water, but becoming soft, viscid, and remarkably sticky like bird-lime, reassuming, as it cools, its original character.
KEG. A cask containing five gallons.

KEEVE, a mining term. A large vat used in dressing ores: also a breeder's term for a mash tub.

KEIR. A boiler used in bleaching establishments. See BLEACHING.

KNIFE-CLEANING MACHINES. Mr. Kent's machine for this purpose consists of a box or case, containing a couple of wooden discs, fixed near to each other upon a horizontal iron rod or spindle, which passes through the case, and is caused to rotate by means of a winch-handle. Each disc is, for about three-fourths of the area of its inner face, covered with alternate rows of bristles and strips of leather; and the remaining fourth part is covered with bristles only. The knife-blades to be cleaned are introduced through the openings in the case, between the rubbing surfaces of the discs; and rotatory motion being given to the discs by a winch-handle, the knives are rapidly cleaned and polished.

Mr. Masters constructed knife-cleaning machines upon the same plan as the above; but the rubbing surface of each disc is formed of strips of buff leather, with only a narrow circle of bristles around the edge of each surface, to clean the shoulders of the knives; small brushes are fixed beneath the holes in the case, through which the blades of the knives are inserted, to prevent the exit of dust from the apparatus.

Mr. Price has also devised a machine for cleaning knives, and another for cleaning forks. The knife-cleaner consists of a horizontal drum, covered with pieces of leather or felt, and fixed within another drum or circular framing, lined with leather or felt. The knives are introduced through openings in a movable circular plate, at the front of the outer casing, and enter between the surfaces of the two drums. The plate is fixed upon a horizontal axis, which extends through the case, and is furnished at the back with a handle; by turning which the disc is caused to rotate and carry round the knives between the surfaces of the drums. The fork-cleaner consists of a box, with a long rectangular opening in the side; behind which two brushes are fixed, face to face. Between these brushes the prongs of the forks are introduced, and the handles are secured in a carrier, which is made to advance and recede alternately by means of a throw-crank, and thereby thrust the prongs into and draw them out of contact with the brushes. The carrier consists of two metal plates, the lower one carrying a cushion of vulcanized India-rubber for the fork handles to rest upon, and the upper being lined with leather; they are hinged together at one end, and are connected at the other, when the handles have been placed between them, by a thumb-screw.

KREOSOTE, or CREOSOTE. One of the many singular bodies discovered by Reichenbach in wood tar. It derives its name from χρήσις and σέριος, I preserve, in allusion to its remarkable antiseptic properties. A great deal of confusion exists in the published accounts of wood creosote, owing to the variable nature of the results obtained by the chemists who have examined it. This confusion is not found with that from coal, which undoubtedly contains two homologous bodies, C₆H₅O₂ and C₆H₅O₂; the first being carbolic, and the second cresylic acid. The composition of carbolic acid has long been known, owing to the researches of Laurent: cresylic acid was recently discovered by Williamson and Fairlie. Commercial coalcreosote sometimes consists almost entirely of cresylic acid. Coal oils, of very high boiling point, contain acids apparently homologues of carbolic acid, higher up in the series than even cresylic acid, and yet perfectly soluble in potash. (Greville Williams.) There is little doubt that wood creosote consists essentially of the same substances as that from coal. The great difference in the odor arises chiefly from the fact of the product from coal retaining with obstinacy traces of naphthylene, paravolining, and chinoline, all of which are extremely odorous. No creosote found in commerce is ever perfectly homogeneous, nor, in fact, is it necessary that it should be so. If perfectly soluble in potash and acetic acid of the density 1070, and if it does not become colored by exposure to the air, it may be considered pure enough for all medicinal purposes. The oils from wood and coal tar may be made to yield creosote by the following process:—The oils are to be rectified until the more volatile portions (which are lighter than water) have passed over. As soon as the product running from the still sinks in water the receiver is to be changed, and the oils may be received until the temperature required to send over the oil is as high as 480° F. The oil so obtained is to be dissolved in caustic soda, all insoluble in it being rejected. The alkaline solution, after being mechanically separated, as far as possible, from the insoluble oil, is to be boiled for a very short time. Two advantages are gained by this operation:—any volatile bases become expelled, and a substance which has a tendency to become brown on keeping, is destroyed. Sometimes the oil on treatment with potash yields a quantity of a crystalline paste. This is naphthylene, and should be removed by filtration through coarse calico or canvas. The alkaline liquid is then to be super-saturated with dilute sulphuric acid, on which the creosote separates and rises in the form of an oil to the surface. This creosote is already free from the greater number of impurities, and, if rectified, may be used for many purposes. To obtain a pure article the operations explained are to be performed with a solution in caustic soda not to be precipitated. The alkaline solution, on boiling again becomes colored, the purification must be gone through a third time. It
is essential not to boil the alkaline solution long, or a serious loss of cresote would take place. According to Reichenbach the boiling point of cresote is 397°. Carbolic acid boils between 309° and 370°. Cresylic acid boils at 397°. From this it would appear that Reichenbach’s cresote consisted of cresylic acid. The specific gravity of cresote according to Reichenbach is 1.037 at 68°. That of carbolic acid is 1.065 at 64°. Carbolic acid and its homologues, when mixed with quicklime and exposed to the air, yield a beautiful red color, owing to the formation of resollic acid.—C. G. W.

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LACTIC ACID, \(\text{C}_4\text{H}_6\text{O}_5\). Syn. Nanceic acid. (\textit{Acide lactique}, Fr.; \textit{Milchsaure}, Germ.) Discovered by Scheele in sour milk. Subsequently, M. Braconnot examined the sour liquid which floats above starch during its manufacture, also the acidified deoxygen of various vegetables, including beet-root, carrots, peas, &c., and found an acid which he considered to be peculiar, and consequently named the nanceic. The acid formed under all these circumstances turns out to be the same; it is, in fact, lactic acid, which modern researches show to be a constant product of the fermentation of sugar, starch, and bodies of that class. The acidity of sauerkraut is due to the presence of the same substance. Liebig has recently extended and confirmed the experiments made many years ago by Berzelius, on the presence of lactic acid in the juice of flesh, but he denies its existence in urine, as asserted by MM. Cap and Henry, and others.

Lactic acid is a colorless syrupy liquid of a powerful pure acid taste. Its specific gravity is 1.215. It is birefringent, consequently the general formula for the lactates is \(\text{C}_4\text{H}_6\text{O}_5\) \(\text{O}^+\text{2MO}^-\); M representing any metal.

The most important salts of lactic acid are those of zinc and lime. The former salt is the one generally formed in examining animal or vegetable fluids with a view to the isolation of the acid. It is found with two different quantities of water, according to the circumstances under which it is prepared, and it is worthy of remark that the amount of water of crystallization remarkably affects the solubility of the salt in water and alcohol.

Lactic acid is produced from alanine by the action of nitrous acid according to the following equation:

\[
2\text{C}_2\text{H}_4\text{NO}^+ + 2\text{NO}^- = \text{C}_4\text{H}_6\text{O}_5^+ + \text{N}_2 + 2\text{H}_2\text{O}.
\]

Alanine, Lactic acid.

Anhydrous lactic acid, \(\text{C}_4\text{H}_6\text{O}_5\), is produced by the action of heat on the syrupy acid. Lactic acid is considered by chemists to be constructed on the type of four atoms of water in which two atoms of hydrogen are replaced by the radical lactyl, thus:

\[
\text{C}_4\text{H}_6\text{O}_5^+ \quad \text{H}^+ \quad \text{O}^-.\n\]

The former two atoms of hydrogen are consequently basic. It has been said that lactic acid may, by fermentation, be converted into butyric acid; the following equation represents the metamorphosis:

\[
\text{C}_4\text{H}_6\text{O}_5^+ = \text{C}_4\text{H}_4^+ + 4\text{CO}_2 + 4\text{H}.
\]

Lactic acid, Butyric acid.

All the butyric acid employed for the preparation of butyric ether, or pine-apple essence, is now prepared by the fermentation of lactate of lime.—C. G. W.

LACUSTRINE FORMATION (a geological term). Belonging to a lake.

LAMP-BLACK. Every person knows that when the combustion of oil in a lamp is imperfect, it pours forth a volume of dense black soot. According to the quantity of carbon contained in the material employed, so is the illuminating power of the flame produced by combustion. If, therefore, we have a very brilliant flame, and we subject it to any conditions which shall impede the progress of the combination of the carbon with the oxygen of the air, the result is at once the formation of solid carbon, or lamp-black. This is exhibited in a remarkable and often an annoying manner by the camphene lamp. If oil of turpentine, resin, pitch oil, or fat oil, be burnt in lamps under a hood, with either a rapid draught or an insufficient supply of air, the lamp-black collects on the hood, and is occasionally removed. Sometimes a metallic roller, generally of tin, is made to revolve in the flame, and rub against a brush. By the cooling influence of the metal, the heat of the flame is diminished, the combustion retarded, and the carbon deposited, and in the evolution of the cylinder swept off. Camphor burning forms a very beautiful black, which is sometimes used as a pigment.

The common varieties of lamp-black are made from all sorts of refuse resinous matters, and from the rejected fragments of pine trees, &c. In Germany, a long flue is constructed in connection with the furnace, in which the resinous substances are burnt, and this flue communicates with a hood, composed of a loose woollen cloth, held up by a rope passing over a pulley. Upon this the soot collects, and is from time to time shaken down. In the best
conducted manufactories about 3 cwt. of lamp-black is collected in each hood in about twelve hours. In England, lamp-black is sometimes prepared from the refuse coking coal, or it is obtained in connection with coke ovens. The lamp-black, however, obtained from the combustion of coal or woody matter is never pure. See Bone Black.

LAMPS. Lamps are very varied in form, and equally varied in the principles involved. A brief description, however, of a few of the modern varieties must suffice.

The moderator lamp.—The spiral spring has recently been introduced into the moderator lamps, for the purpose of forcing the oil up the wick of the lamp. This will be understood by the following description and drawings:—The distinguishing character of the moderator lamp is the direct transmission of the power, in the reservoir of oil, to the reservoir offered by the weight of the column of oil, as it rises to the cotton;—and secondly, the introduction of a rectangular regulator, which equilibrates constantly by the resistance of the oil and the force applied to raise it. In the reservoir (fig. 367) is a spiral spring which presses on the disc or piston, (fig. 368,) which is furnished with a valve opening downwards. This spring is attached to a tooth rack, worked by a pinion wheel, by the means of which it is wound up. The mechanical force of the spring is equal to from 15 to 20 pounds; and as this force is exerted upon the disc, floating on the oil, this is forced up through the tube, and it overflows to the argand burner, thoroughly saturating the cotton, and supplying a constant stream of oil. This oil falls back into the reservoir, and is, of course, above the disc. When the spring has run down, it is again wound up; and then the valve opening downwards allows the oil to flow back beneath the disc, to be again forced up through the tube. As the pressure employed is so great, the oil would, but for the "moderator," flow with too much rapidity. This moderator, or regulator, is a tapering rod of iron-wire which is placed in the ascending tube; and, as the pressure increases, it is forced more into it, and checks the flow of oil; whereas, as it diminishes it falls, and being tapering, allows more oil to rise. Several ingenious adjustments are introduced into these lamps, as manufactured by the Messrs. Tylor of Warwick Lane, with which we need not at present deal. The cylinders containing the oil are covered with cases in metal or sometimes of porcelain. Two drawings of these are shown (fig. 369 and fig. 370). These lamps admit evidently of yet more elegant forms than have been given them. The urn-shaped, from the antique, in very pure taste, is the last introduction of the house above named.

It would be tedious to enumerate the various modifications of form and action to which the oil lamp has been subject, previous to its arrival at what may be deemed its perfect construction by Argand. The discovery of the mode of applying a new principle by this in-
LAMPS.

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individual not only produced an entire revolution in the manufacture of the article, but threatened with ruin all those whom the patent excluded from participation in the new trade; so much so, indeed, that Argand, who had not been apprenticed to the business, was publicly persecuted by the painters, locksmiths, and ironmongers, who disputed his right by any improvements to infringe the profits of their chartered vocation. "This invention," to quote a description of the lamp published some years ago, "embraces so many improvements upon the common lamp, and has become so general throughout Europe, that it may be justly ranked among the greatest discoveries of the age. As a substitute for the candle, it has the advantage of great economy and convenience, with much greater brilliancy; and for the purpose of producing heat, it is an important instrument in the hands of the chemist. We may, with some propriety," continues this authority, "compare the common lamp and the candle to fire made in the open air, without any forced method of supplying it with oxygen; while the Argand lamp may be compared to a fire in a furnace, in which a rapid supply of oxygen is furnished by the velocity of the ascending current. This, however, is not the only advantage of this valuable invention. It is obvious that, if the combustible vapor occupies a considerable area, the oxygen of the atmosphere cannot combine with the vapor in the middle part of the ascending column. The outside, therefore, is the only part which enters into combustion; the middle constituting smoke. This evil is obviated in the Argand lamp, by directing a current of atmospheric air through the flame, which, instead of being raised from a solid wick, is produced from a circular one, which surrounds the tube through which the air ascends."

The mechanism of the Argand burner, in its present improved state, will be clearly understood from the annexed figures and explanation, which apply equally to each description of the lamps hereafter described.

\[\alpha(p. 371)\] is a brass tube, about 3½ inches in length, and 1½ inch wide; within this tube is placed another, \(\beta\), which is soldered fast inside by the flange at \(c\); the space between these tubes contains the oil surrounding the wick, and which, being freely admitted from the reservoir by the side pipes \(d, e\), rises in the tubular space, either to a height corresponding with its level in the reservoir, or at least so as to maintain the wick in a state of constant saturation. The tube \(\beta\) is of considerable thickness, having a spiral groove cut about it from top to bottom; \(\varphi\) is a metallic ring made to slip over the tube \(\alpha\); it contains a short pin inside, which fits exactly into the spiral groove just mentioned; \(\alpha\) is the circular wavy cotton wick, the lower end of which is drawn tight upon the neck of the ring; \(\nu\) is a copper tube, with a slit nearly from top to bottom; it admits the ring \(\varphi\), and being dropped over the inner tube \(\alpha\), exactly fits the inside of the wider tube \(\lambda\), by means of a narrow rim near the top at \(\epsilon\), and another at the bottom \(b\): between the upper rim and the margin, there is a small projecting pin \(\epsilon\), which, when the whole apparatus is combined, fits into the cavity \(c\) of the collar \(i\). To prepare the lamp for use, the tube \(\nu\) is placed between \(\lambda\) and \(\alpha\), as just described; the ring \(\varphi\), with its charge of cotton, is next inserted, the pin in the inside falling into the spiral groove, and that on the outside entering the slit in the tube \(\alpha\), which, on being turned about, moves the ring \(\varphi\) down upon the screwed inner tube, until the wick only just rises above the superior edges of the tubes, in the interval between which it lies in the oil. In this stage, the frame \(r\) is placed on the nick in the collar at \(e\), falling upon the pin near the top of \(\nu\); the lower disc \(f, p\), passing over the tube \(\lambda\), at once presents a convenient support for the glass chimney, and a finger-hold for raising the wick. The central tube is open throughout, communicating, at its lower end, with the brass receptacle \(k\); the latter is perforated at top, to admit the air which, by circulating through the above tube, and the hollow flame which surrounds it, causes the lamp to burn with that peculiar freedom and brilliancy which distinguishes the Argand construction. This last-mentioned receptacle likewise catches any small quantity of oil which may pass over the inner tube during the combustion of the wick. \(l\) is the brass peg which fits into the upper part of the pillar, in the table lamp.

In addition to the endless variety of small portable lamps, the peculiarities of which it would be tedious to particularize, and the merit of which, as compared with those on the Argand principle, consists, for the most part, in their cheapness, the more important articles, and those generally in demand, may be distinguished as fixed or bracket lamps, suspended or chandelier lamps, and table or French lamps—all these having burners on the principle above described. The former sort were, previous to the introduction of gas, very
common in shops. The globe $A$, (fig. 372,) which is sometimes made plain and sometimes embossed, as in the cut, screws off when the oil is poured in at an opening in the lower part, which is afterwards closed by means of a slide attached to the stem $b$, and the globe, thus replenished, is inverted and screwed into the part $c$. When the lamp is used, the stem $b$ is raised a little, and the oil is suffered to flow through the intermediate tube into the cistern $d$, only at the rate at which it is consumed by the burning of the wick. The peculiar form of the glass chimney $f$ is admirably calculated to assist in the more complete combustion of the matter drawn up to the wick when impure oil is used, a device which was originally in part secured by placing over the central tube, and in the midst of the flame, a circular metal plate, by means of which the ascending column of air was turned out of its perpendicular course, and thrown immediately into that part of the flame where the smoke is formed, and which by this ingenious contrivance is effectually consumed; this application, however, is not necessary, nor the form of much moment, when purified sperm oil is used. These lamps being usually made to move on a pivot at $f$, attached to the wall or other support, are very convenient in many situations, as being easily advanced over a desk or counter, and afterwards turned aside when not in use. The seminatural lamp having passed out of use need not be described.

The use of spirit lamps followed, and we have the naphtha and camphene lamps of this order. The accompanying woodcut (fig. 373) shows the peculiarity of the camphene lamp where the reservoir of spirit (turpentine deprived of smell) is far below the burner, to which it ascends by capillary attraction, through the tubes of the cotton wick. Lamps to burn naphtha (Belmontina, &c.) are constructed on the same principle.

One of the best oil lamp is that known as Carcel's lamp. In this lamp the oil is raised through tubes by clock-work, so as continually to overflow at the bottom of the burning wick; thus keeping it thoroughly soaked, while the excess of the oil drops back into the cistern below. I have possessed for several years an excellent lamp of this description, which performs most satisfactorily; but it can hardly be trusted in the hands of a servant; and when it gets at all deranged, it must be sent to its constructor in Paris to be repaired. The light of this lamp, when furnished with an appropriate tall glass chimney, is very brilliant, though not perfectly uniform; since it fluctuates a little, but always perceptibly to a nice observer, with the alternating action of the pump-work; becoming dimmer after every successive jet of oil, and brighter just before its return. The flame, moreover, always flickers more or less, owing to the powerful draught, and rectangular reverberatory shoulder of the chimney. The mechanical lamp is, however, remarkable for continuing to burn, not only with unabated but with increasing splendor for seven or eight hours; the vivacity of the combustion increasing evidently with the increased temperature and fluidity of the oil, which by its ceaseless circulation through the ignited wick, gets eventually pretty warm. In the comparative experiments made upon different lights by the Parisian philosophers, the mechanical lamp is commonly taken as the standard. I do not think it entitled to this pre-eminence: for it may be made to emit very different quantities of light,
LEAD.

according to differences in the nature and supply of the oil, as well as variations in the form and position of the chimney. Besides, such lamps are too rare in this country to be selected as standards of illumination.

LAMPIC ACID. (Acide Lampique, Fr.) If a little ether be placed at the bottom of a glass, and some spongy platinum attached to a wire of the same metal be ignited and suspended about an inch from the fluid, it will glow and continue to do so for a long time. On the other hand, if a spiral of platinum wire be placed over the wick of a spirit lamp, and the latter be first ignited and then blown out, the wire will continue at a red heat until all the spirit is exhausted. Numerous sesquioxide, when placed warm on wire gauze over capsules containing alcohol, will glow in the same manner. Under all these circumstances, a powerful odor resembling aldehyde is evolved, which strongly affects the eyes. If this experiment be made in such a manner that the volatile product may be condensed, it will be found to be strongly acid. It is powerfully reducing in its tendency, and if heated with the oxides of silver or gold, converts them into the metallic state, and the liquid is found to contain acetic acid and resin of aldehyde. If, however, the acid liquid be only very gently warmed with oxide of silver, a portion of the latter is dissolved; but when baryta is added to precipitate the silver as oxide, and the fluid is warmed, the metal instead of the oxide comes down, and the fluid when tested for the nature of the acid, is found to contain nothing but acetate of baryta. These phenomena are explained by some chemists by supposing the fluid to contain an acid which they, following the late Professor Daniell, call the lampic, and supposed to contain $\text{C}_3\text{HO}_4$. When lampic acid is treated first with oxide of silver and then with baryta water, and heated, they consider that the oxygen of the oxide of silver is transferred to the lampic acid, converting it into acetic acid, which combines with the baryta, while the metallic silver is precipitated. The following equation explains the reaction supposed to take place:

$$\text{C}_3\text{HO}_4 + \text{BaO} = \text{C}_3\text{HO}_4\text{BaO} + \text{Ag} + \text{HO}.$$  

Lampic acid. Acetate of baryta.

The conversion of the lampic into acetic acid is therefore attributed to the oxidizing tendency of the oxide of silver. Those who regard the decomposition from the above point of view consider lampic acid to be acetylic acid, that is to say, to bear the same relation to acetic acid (acetic acid) that sulphurous acid does to sulphuric acid.

The above explanation, although simple, does not really render a satisfactory account of the reactions which bear upon the subject. Aldehyde, when treated with oxide of silver, does, it is true, become converted into the same, or apparently the same, substance as lampic acid, but the probabilities are in favor of Gerhardt's supposition, that the lampates are in fact aldehyde, in which an equivalent of hydrogen is replaced by a metal. That the aldehydes are capable of uniting with metals with elimination of hydrogen has been, on more than one occasion, proved by experiment. There is great difficulty in preparing the sodium aldehyde of the vinic series, but the author of this article has found that if enolic aldehyde from oil of rue be treated with sodium, a definite compound is formed, having the formula $\text{C}_4\text{HO}_4\text{Na}$. If, therefore, we admit aldehyde to be formed on the hydrogen type, that is to say, two atoms of hydrogen in which one is replaced by the oxidized radical acetyl, we shall have for aldehyde, $\text{C}_4\text{HO}_4\text{H}^+$; and for the lampates, acetylics, or aldehydes, $\text{C}_4\text{HO}_4\text{M}^-$. M. Gerhardt, who views the lampates in the above light, regards aldehyde as the true acetyl acid. See Arrhenius. — C. G. W.

LAPS. Metal polishing wheels. Metal wheels or laps made of nearly every metal and alloy in common use, have been more or less employed in the mechanical arts as vehicles for the application of several of the polishing powders. But of all laps, notwithstanding their variety, those of lead, slightly alloyed, and supplied with powdered emery, render the most conspicuous service. Generally the plane, or flat surface of the lap, is employed; at other times the cylindrical edge, as by cutters; but the portion actually used is in either case called the face of the lap. There are several kinds of laps. The lap is in some cases a thin disc of metal, fixed by means of a screwed nut against a shoulder on the spindle, but it is better with lead laps to employ an iron plate cast full of holes, to support the softer metal. The casting mould may in this case be either an iron disc, with a central screw to fix the iron centre plate at the time of pouring, or the mould may be made of sand, and in halves, after the usual manner of the foundry. In either case the iron plate should be made as hot as the fluid metal, which, by entering the holes, becomes firmly united to the iron, especially if the holes are largest on the reverse side, or that away from the lead. — Holtzapfel.

Lap is also a roll or sliver of cotton for feeding the cards of a spinning machine.

LEAD. Although lead forms an essential element in a large number of minerals, the ores of this metal are, strictly speaking, far from numerous. Of these the most important
is sulphide of lead, or galena. This mineral, which possesses a metallic brilliancy, and has a lighter color than metallic lead, presents, in its cleavage, all the variations from large facets and laminae indicating a cubic crystallization to a most minutely granular structure. It is extremely brittle, and its powder presents a brilliant blackish-gray appearance.

The specific gravity of galena is 7.5 to 7.8, and its composition, when absolutely pure, is:

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<tbody>
<tr>
<td>Lead</td>
<td></td>
<td></td>
<td></td>
<td>86.55</td>
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<tr>
<td>Sulphur</td>
<td></td>
<td></td>
<td></td>
<td>13.45</td>
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100.00

Galena is, however, but seldom found chemically pure, as, in addition to variable quantities of earthy impurities, it almost always contains a certain amount of silver. It is usually observed that galena presenting large facets is less argentiferous than those varieties having a closer grain, and that finely granular stellate specimens generally afford the largest amount of silver.

It would appear, from recent experiments, that the silver contained in the finely-granular varieties of galena often occurs in the form of sulphide of silver, not chemically intermixed, whilst in the more flaky descriptions of this ore, the sulphides of lead and silver are chemically combined.

Galena occurs in beds and veins, in gratae, gneiss, clay-slate, limestone, and sandstone rocks.

In Spain it is found in the granite hills of Lannás and elsewhere; at Frielberg in Saxony it occupies veins in gneisses; in the Harz, Bohemia, Cornwall, and many other localities, it is found in killas, or clay-slate. The rich deposits of Derbyshire, Cumberland, and the northern districts of England, are in the mountain limestone, whilst at Commin, near Alx-la-Chapelle, large quantities of this ore are found disseminated in the Bunter sandstone.

This mineral is frequently associated with blende, iron and copper pyrites, the carbonate and other ores of lead, and usually occurs in a gangue of sulphate of baryta, calcareous, spar-those iron, or quartz. It is also not unfrequently associated with fluor spar.

The next most important ore of lead is the carbonate, which is a brittle mineral, of a white or grayish-white color, having a specific gravity varying from 6.46 to 6.50. Its composition is:

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<tbody>
<tr>
<td>Carbonic acid</td>
<td></td>
<td></td>
<td></td>
<td>16.85</td>
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<tr>
<td>Oxide of lead</td>
<td></td>
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<td></td>
<td>83.15</td>
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99.61

Large quantities of this substance occur in the mines of the Mississippi Valley in the United States of America, where they were formerly thrown away as useless, but have since been collected and smelted. Vast deposits of this substance have also been found in the Bunter sandstone, near Duren, in Prussia, and at Freynge, in Bavaria. In the two latter localities it appears to form the cement holding together the grains of quartz, of which the sandstone principally consists. These ores, which yield from 14 to 20 per cent. of metal, do not readily admit of being concentrated by washing.

The sulphate of lead does not often occur in sufficient quantities to be employed as an ore of that metal. In appearance it is not unlike the carbonate, but may readily be distinguished from it by its not dissolving with effervescence in nitric acid.

Its specific gravity is from 5.25 to 6.20, and its composition is:

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</thead>
<tbody>
<tr>
<td>Sulphuric acid</td>
<td></td>
<td></td>
<td></td>
<td>25.65</td>
</tr>
<tr>
<td>Oxide of lead</td>
<td></td>
<td></td>
<td></td>
<td>74.35</td>
</tr>
</tbody>
</table>

99.70

This ore of lead usually results from the oxidation of galena. At St. Martin's, near the Vega de Ribaaldeo, in Spain, this mineral, more or less mixed with the phosphate of lead, is found in sufficient quantities to be made, on a small scale, the subject of an especial metallurgical treatment. Large quantities of sulphate of lead ores are also annually imported into this country from the mines in Australia. These ores contain on an average 35 per cent. of lead, and 35 oz. of silver to the ton of ore, together with a little gold.

Phosphate of lead, when crystallized, usually presents the appearance of hexagonal prisms, of a bright-green, brown, or yellowish color. Its specific gravity varies from 4.5 to 7.1. This mineral is composed of a mixture of true phosphate of lead, phosphate of lime, chloride of lead, and fluoride of calcium, and usually contains about 78 per cent. of oxide of lead. In Spain, it occurs in botryoidal forms, in connection with the sulphate of the same metal, and is treated in blast furnaces for the lead it affords.

The other minerals containing lead seldom occur in sufficient quantities to be of much importance to the smelter, and may therefore be disregarded in the present article.

The extraction and mechanical preparation of ores is the business of the miner, and not
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of the metallurgist, who receives them from the former freed as perfectly as possible from foreign matters.

The metallurgical processes by the aid of which lead is obtained from galena, may be divided into two classes. The first of these is founded on the following reactions:—If one equivalent of sulphide of lead and two equivalents of the oxide of the same metal are fused together, the result is three equivalents of metallic lead and one equivalent of sulphurous acid, which is evolved.

This reaction is represented by the following equation:—

\[ \text{PbS} + 2\text{PbO} = 3\text{Pb} + \text{SO}_2 \]

When, on the other hand, one equivalent of sulphide of lead and one equivalent of sulphate of lead are similarly treated, two equivalents of lead are obtained, and two equivalents of sulphurous acid gas evolved. Thus:—

\[ \text{PbS} + \text{PbO}_3 \text{SO}_4 = 2\text{Pb} + 2\text{SO}_2 \]

The process, founded on the foregoing reactions, and which we will distinguish as the method by double decomposition, consists in roasting the galena in a reverberatory furnace until a certain amount of oxide and sulphate has been formed, and subsequently, after having intimately mixed the charge and closed the doors of the furnace, causing the whole to enter into a state of fusion.

During this second stage of the operation, the reaction between the sulphides, sulphates, and oxides takes place, and metallic lead is eliminated. The roasting of the ore is, in some cases, conducted in the same furnace in which the fusion is effected, whilst in others two separate furnaces are employed.

The process by double decomposition is best adapted for the richer varieties of ore, and such as are least contaminated by silicious or earthy impurities, and is consequently that which is almost universally employed for smelting the ores of this country.

By the second method, which we will call the process by affinity, the ore is fused with a mixture of metallic iron, which, by combining with the sulphur, liberates the metallic lead. This reaction will be understood by reference to the following formula:—

\[ \text{PbS} + \text{Fe} = \text{Pb} + \text{FeS} \]

In practice, however, metallic iron is not always employed for this purpose; cast iron is also frequently used, and in some instances the ores of iron and hammer slags are substituted, as are also tap-cinder and other secondary products containing a considerable percentage of this metal. None of these substances are, however, found to be so efficacious as metallic iron, since cast iron requires to be decarburized before it can readily decompose the sulphide of lead, and the ores of iron require the introduction of various fluxes, and the consequent expenditure of an additional amount of fuel. In all cases, however, it is judicious to subject the ore to a preliminary roasting, in order to eliminate a portion of the sulphur, and thereby reduce the expenditure of iron, as well as to agglomerate the ore and render it better adapted for its subsequent treatment in the blast furnace.

We will not attempt to describe the different forms given to roasting furnaces employed for the ores treated by this process, but would remark that they frequently resemble the kilns used for the preparation of lime, whilst in some instances the ores are roasted in heaps interstratified with wood or other fuel.

The method of treating ore by affinity is particularly adapted to those varieties that contain a considerable amount of silica, since such minerals, if treated by double decomposition, would, by the formation of oxide of lead, give rise to silicates, from which it would be exceedingly difficult to extract the metal.

English process. Treatment by double decomposition.—Galena, if placed in a close vessel which protects it from the action of the air, and exposed to a gradually increasing temperature, becomes fused without the elimination of any lead taking place, but ultimately a portion of the sulphur is driven off, and a subsulphide is formed, which at a very elevated temperature is volatilized without change.

If, however, the vessel be uncovered, and the air allowed to act on its contents, oxygen combines with the sulphur, sulphurous acid is evolved, and the desulphuration of the mineral is slowly effected.

When galena is spread on the hearth of a reverberatory furnace, and is so placed as to present the largest possible amount of surface to oxidizing influences, it will be found that the surface slowly becomes covered with a yellowish-white crust of sulphate of lead. The oxygen of the air, by combining with the two elementary bodies of which galena is composed, will evidently produce this effect. This is not, however, the only chemical change which takes place in the charge under these circumstances: oxide of lead is produced at the same time as the sulphate, or rather the formation of the oxide is prior to that of the sulphate.

In fact, during the first stage of the operation of roasting sulphurous acid is evolved, the sulphur joins the lead, and a portion of that metal remains in a free state. This becomes oxidized by the air passing through the furnace, and subsequently a part of it com-
bines with sulphuric acid, formed by the oxidation of sulphurous acid, and sulphate of lead is the result. In this way, after the expiration of a certain period, both oxide and sulphate of lead are present in the furnaces.

During the early period of the roasting, when the temperature of the furnaces is not very elevated, the proportion of sulphate is larger than that of the oxide formed, but in proportion as the heat of the apparatus increases, the production of oxide becomes more considerable, whilst that of the sulphate diminishes.

The sulphate and oxide thus formed re-act in their turn on the undecomposed galena, whilst a portion of the latter, by combining with the sulphide of lead, gives rise to the formation of oxysulphide.

This last compound has no action on galena, except to dissolve it in certain proportions, but is readily decomposed by the aid of carbonaceous matter.

It is therefore evident that the addition of carbon, at this stage of the operation, will have the effect of reducing the oxide and oxysulphide of lead.

Every process that has for its object the reduction of lead ores by double decomposition, comprises two principal operations:—1st. The reduction of galena, by the aid of heat and atmospheric air, to a mixture of sulphide, oxide, and sulphate, which mutually decompose each other, with the elimination of metallic lead. 2d. The reduction of the oxysulphide by the addition of carbonaceous matter.

The reverberatory furnace.—The reverberatory furnace employed for the treatment of galena is composed, like all other furnaces of this description, of three distinct parts, the fire-place, the hearth, and the chimney.

The hearth has to a certain extent the form of a funnel, of which the lowest point is on the front side of the furnace immediately below the middle door. The molten metal descending from every side along the inclined bottom or sole, is collected in this receptacle, and is ultimately run off by means of a proper tap-hole. This tap-hole is, during the operation, closed by a pellet of clay.

The inclination of the hearth is more rapid in the vicinity of the fire-bridge than towards the chimney, in order that the liquid metal may not be too long exposed to the oxidizing and volatilizing influences of a current of strongly-heated air.

The dimensions given to these furnaces, as well as the weight of the charge operated on at one time, vary considerably in different localities, but in the north of England the following measurements are usually employed.—The fire-grate is 5 ft. 9 in. × 1 ft. 10 in., and the thickness of the fire-bridge 1 ft. 5 in.; the length of the sole is 9 ft., and its average width 7 ft. The depth of the tap is about 2 ft. 6 in. below the top of the inclined sole. The height of the roof at the fire-end may be 1 ft. 4 in., and at the other extremity 11 inches.

The introduction of the charge is in some cases effected by the doors of the furnace, whilst in other instances a hopper, placed over the centre of the arch, is made use of.

On the two sides of the furnace are placed three doors about 11 in. × 9 in., which are distinguished as 1, 2, and 3, counting from the fire-bridge end. The three doors on the one side are known as the front doors, whilst those on the other side are called the back doors. Immediately beneath the door on the front side of the furnace is situated the iron pan into which the molten lead is tapped off.

The bottom of this arrangement is in most cases composed of fire-bricks, covered by a layer of vitrified slags, of greater or less thickness. In order to form this bottom, the slags are introduced into the furnace, the doors closed, and the damper raised. An elevated temperature is thus quickly obtained, and as soon as the scorue have become sufficiently fused, they are, by means of rakes and paddles, made to assume the required form. The charge employed, as before stated, varies in almost every establishment. In the north, however, smaller charges are used than in most other localities. At Newcastle, and in the neighborhood, the charge varies from 12 to 14 cwt.; in Wales, and near Bristol, 21 cwt. charges are treated; whilst in Cornwall, charges of 30 cwt. are not unfrequently worked. The time required for smelting a charge varies with its weight and the nature of the ores, from 6 to 24 hours.

In some cases the ore is introduced raw into the furnace, whilst in others it undergoes a preliminary roasting previous to its introduction. Rich ores are generally smelted without being first calcined, but the poorer varieties, and particularly those which contain large quantities of iron pyrites, are, in most instances, subjected to roasting in a separate furnace.

In order to understand more clearly the operation of smelting in furnaces of this description, we will suppose that a charge has just been tapped off, and that, after thoroughly clearing the hearth, a fresh charge of raw ores has been introduced. During the first part of the operation of roasting, which usually occupies about two hours, the doors are taken off to admit free access of air, and also for the purpose of cooling the furnace, which has been strongly heated at the close of the preceding operation. No fuel is at this period charged upon the grate, since the heat of the furnace is of itself suf-
LEAD.

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cient to effect the elimination of the first portions of sulphur. The ore is carefully
stirred, for the purpose of constantly presenting a fresh surface to oxidizing influences,
and when white fumes are no longer observed to pass off in large quantities, a little coal
may be thrown on the grate, and the temperature gradually elevated until the charge be-
comes slightly clammy and adheres to the rake. When the roasting is considered as
being sufficiently advanced, the smelter turns his attention to the state of the fire, taking
care to remove the clinkers and get the grate into proper condition for the reception of
a fresh supply of fuel. The furnace doors are now closed, and a strong heat is kept up
for about a quarter of an hour, when the smelter examines the condition of his charge
by removing one of the doors. If the operation is progressing satisfactorily, and the
lead flowing freely and passing without obstruction into the tap, the firing is continued a
little longer; but when the ores have been found to have taken fire, or are lying uneven-
ly on the bottom of the furnace, the position of the charge is changed by the use of an
iron paddle. During this operation the furnace becomes partially cooled, and the re-
duction of temperature thus obtained is frequently found to produce decompositions,
which facilitate the reduction of the charge. In the case of extremely refractory ores
this alternate heating and cooling of the furnace is sometimes almost indispensable, whilst,
in other instances, their being once or twice raked over is all the manipulation that is
required.

We will suppose that four hours have now elapsed since the charging of the furnace,
and that the charge has run down the inclined sole towards the tap. The smelter now
examines the condition of the scoriae and adds a couple of shovelfuls of lime and three
or four shovelfuls of small coals, the amount and relative proportions of these being reg-
lated in accordance with the aspect of the slags. The charge is now, by means of
proper tools, again raised to the breast of the furnace, and the firing continued until the
charge has run down into the tap-hole. The foreman now takes his rake and feels if
any lumps remain in an unused condition, and if he finds all to be in a fluid state he calls
his assistant from the other side, and by the addition of a small quantity of lime and fine
coal, makes the slag assume a pasty or rather doughy consistency. By the aid of his
paddle he now pushes this compound up to the opposite side of the furnace, where it is
drawn by an assistant through the back door into a trough containing water. Whilst the
assistant is doing this the foreman is busily engaged in tapping off the metal into the
iron pan in front of the furnace, from which, when sufficiently cooled, it is laded out
into suitable moulds.

The total duration of the operation may be about six hours.

To build a furnace of the above description, 5,000 common bricks, 2,000 fire-bricks,
and 2½ tons of fire-clay are required. In addition to this must be reckoned the iron-
work, the expense of which will be much influenced by the nature of the armatures em-
ployed and the locality in which the furnace is constructed.

The amount of fuel employed for the treatment of a ton of lead ore varies not only
in relation to the richness of the mineral, but is also much influenced by the nature of
the associated matrix and the caloric value of the fuel itself. The loss of metal expe-
rimented during the operation is mainly dependent on the richness of the ore treated and
the skill and attention of the foreman.

In the north about 12 cwt. of coal are consumed in the elaboration of one ton of ore,
and the loss of metal on 60 per cent. ore may be estimated at about 12 per cent., of
which about 6½ per cent. is subsequently recovered from the slag and fumes. At a well-
considered firing-work, situated in the west of England, in which the average quantity
of the ores smelted during the year was 75½ ton, the yield from the smelting furnaces was
68½ per cent., and the coal used per ton of ore was 13½ cwt. The lead recovered from
the slag and fumes amounted to 2½ per cent., making the total yield of metal 71½ per
cent., and the loss on the assay produce 4½ per cent.

In this establishment the men are paid from 7s. 6d. to 12s. 6d. per ton of lead, in
accordance with the nature of the ores operated on.

In one establishment the process before described is somewhat varied. The charge
employed is 21 cwt. This is run down and tapped off at the expiration of 6 hours, and
about 9 pigs of 1½ cwt. each usually obtained. A second charge of 21 cwt. is then dropped
in, and, as soon as it is roasted, mixed with the slags of the former operation. The
whole is then run down in the ordinary way, the slags drawn and the lead tapped off in 9
hours. The produce of the second or double charge is from 14 to 15 pigs.

If the ores are difficult to flow, 16 to 16½ hours are required for the two charges.

A small quantity of black slag from the slag hearth is employed for drying up.

Treatment of lead ore by the Scotch furnace or ore-hearth.—This furnace is generally
employed in the counties of Northumberland, Cumberland, and Durham, for the smelt-
ing of lead ore, which has formerly only been carried to them without any preparation, but they
are now often exposed to a preliminary calcination. The roasted ore yields in the Scotch
furnace a more considerable product than the crude ore, because it forms in the furnace
a more porous mass, and at the same time it works drier, to use the founder's expression; that is, it allows the stream of air impelled by the blast to diffuse itself more completely across the matters contained in the furnace.

In proceeding to smelt by means of an ore-hearth, two workmen are required to be in attendance from the beginning to the end of each smelting shift, the duration of which is from 12 to 15 hours. The first step in commencing a smelting shift is to fill up the hearth-bottom and space below the workstone with peats, placing one already kindled before the nozzle of the bellows. The powerful blast very soon sets the whole in a blaze, and by the addition of small quantities of coal at intervals, a body of fire is obtained, filling the hearth. Boarded ore is now put upon the surface of the fire, between the forestone and pipestone, which immediately becomes heated red hot and reduced, the lead from it sinking down and collecting in the hearth bottom. Other portions of ore of 10 or 12 lbs. each are introduced from time to time, and the contents of the hearth are stirred and kept open, being occasionally drawn out and examined upon the workstone, until the hearth bottom becomes full of lead. The hearth may now be considered in its regular working state, having a mass of heated fuel, mixed with partly fused and semi-reduced ore, called Brouze, floating upon a stratum of melted lead. The smelting shift is then regularly proceeded with by the two workmen, as follows:—The fire being made up, a stratum of ore is spread upon the horizontal surface of the brouze, and the whole suffered to remain exposed to the blast for the space of about five minutes. At the end of that time, one man plunges a poker into the fluid lead in the hearth bottom below the brouze, and raises the whole up, at different places, so as to loosen and open the brouze, and in doing so, to pull a part of it forwards upon the workstone, allowing the recently added ore to sink down into the body of the hearth. The poker is now exchanged for a shovel, with a head 6 inches square, with which the brouze is examined upon the workstone, and any lumps that may have been too much fused, broken to pieces; those which are too hard to be illuminated by the heat as to be quite hard, and further known by their lightness, being picked out, and thrown aside, to be afterwards smelted in the slag hearth.

They are called "gray slags." A little slaked lime, in powder, is then spread upon the brouze, which has been drawn forward upon the workstone, if it exhibit a pasty appearance; and a portion of coal is added to the hearth, if necessary, which the workman knows by experience. In the mean time, his fellow workman, or shoulder fellow, clears the opening, through which the blast passes into the hearth, with a shovel, and places a peat immediately above it, which he holds in its proper situation until it is fixed by the return of all the bronze from the workstone into the hearth. The fire is made up again into the shape before described, a stratum of fresh ore spread upon the part, and the operation of stirring, breaking the lumps upon the workstone, and picking out the hard slags repeated, after the expiration of a few minutes, exactly in the same manner. At every stirring a fresh peat is put above the nozzle of the bellows, which divides the blast, and causes it to be distributed all over the hearth; and as it burns away into light ashes, an opening is left for the blast to issue freely into the body of the brouze. The soft and porous nature of dried peat renders it very suitable for this purpose; but, in some instances, where a deficiency of peats has occurred, blocks of wood of the same size have been used with little disadvantage. As the smelting proceeds, the reduced lead, filtering down through all parts of the bronze into the hearth bottom, flows through the channel, out of which it is laced into a proper mould, and formed into pigs.

The principal particulars to be attended to in managing an ore-hearth properly during the smelting shift, are these: First.—It is very important to employ a proper blast, which should be carefully regulated, so as to be neither too weak nor too powerful. Too weak a blast would not excite the requisite heat to reduce the ore, and one too powerful has the effect of fusing the contents of the hearth into slags. In this particular no certain rules can be given; for the same blast is not suitable for every variety of ore. Soft fine-grained galena, of great specific gravity, being very fusible, and easily reduced, requires a moderate blast; while the harder and lighter varieties, many of which contain more or less iron, and are often found rich in silver, require a blast considerably stronger. In all cases, it is most essential that the blast should be no more than sufficient to reduce the ore, after every other necessary precaution is taken in working the hearth. Second.—The blast should be as much divided as possible, and made to pass through every part of the brouze. Third.—The hearth should be vigorously stirred, at due intervals, and part of its contents exposed upon the workstone; when the partially fused lumps should be well broken to pieces, as well as those which are further vitrified, so as to form slags, carefully picked out. This breaking to pieces and exposure of the hottest part of the bronze upon the workstone, has a most beneficial effect in promoting its reduction into lead; for the atmospheric air immediately acts upon it, and, in that heated state, the sulphur is readily consumed, or converted into sulphurous acid, leaving the lead in its metallic state; hence it is that the reduced lead always flows most abundantly out of the hearth immediately after the return of the brouze, which has been spread out and ex-
posed to the atmosphere. Fourth.—The quantity of lime used should be no more than is just necessary to thin the brouze sufficiently; as it does not in the least contribute to reduce the ore by any chemical effect; its use is merely to render the brouze less pasty, if, from the heat being too great, or from the nature of the ore, it has a disposition to become very soft. Fifth.—Coal should be also supplied judiciously; too much unnecessarily increasing the bulk of the brouze, and causing the hearth to get too full.

When the ore is of a description to smelt readily, and the hearth is well managed in every particular, it works with but a small quantity of brouze, which feels dry when stirred, and is easily kept open and permeable to the blast. The reduction proceeds rapidly with a moderate degree of heat, and the slags produced are inconsiderable: but if in this state the stirring of the brouze and exposure upon the workstone are discontinued, or practiced at longer intervals, the hearth quickly gets too hot, and immediately begins to agglutinate together; rendering evident the necessity of these operations to the successful management of the process. It is not difficult to understand why these effects take place, when it is considered, that in smelting by means of the ore-hearth, it is the oxygen of the blast and of the atmosphere which principally accomplishes the reduction; and the point to be chiefly attended to consists in exposing the ore to its action, at the proper temperature, and under the most favorable circumstances. The importance of having the ore free from impurities is also evident; for the stony or earthy matter it contains impedes the smelting process, and increases the quantity of slags. A very slight difference of composition of perfectly dressed ore may readily be understood to affect its reducibility; and hence it is, that ore from different veins, or the same vein in different strata, as before observed, is frequently found to work very differently when smelted singly in the hearth. It happens, therefore, that with the best workmen, some varieties of ore require more coal and lime, and a greater degree of heat than others; and it is for this reason that the forestone is made movable, so as either to answer for ore which works with a large or a small quantity of brouze.

It has been stated that the duration of a smelting shift is from 12 to 15 hours, at the end of which time, with every precaution, the hearth is apt to become too hot, and it is necessary to stop for some time, in order that it may cool. At mills where the smelting shifts is 12 hours, the hearths usually go on 12 hours, and are suspended 3; four and a half or five shifts* of ore (30 to 40 cwt.) are smelted during a shift, and the two men who manage the hearth work each four shifts per week: terminating their week's work at 3 o'clock on Wednesday afternoon. They are succeeded by two other workmen, who also work four 12-hour shifts; the last of which they finish at 4 o'clock on Saturday. In these eight shifts from 30 to 40 bings of ore are smelted, which, when of good quality, produce from 9 to 10 fodders of lead. At other mills where the shift is 14 or 15 hours, the furnace is kindled at 4 o'clock in the morning, and worked until 6 or 7 in the evening each day, six days in the week; during this shift, 5 or 5½ bings of ore are smelted, and two men at one hearth, in the early part of each week, work three such shifts, producing about 4 fodders of lead—two other men work each 3 shifts in the latter part of the week, making the total quantity smelted per week, in one hearth, from 50 to 55 bings.

Hearth-ends and Smelter's fame.——In the operation of smelting, as already described, it happens that particles of unreduced and semi-reduced ore are continually expelled from the hearth, partly by the force of the blast, but principally by the decrepitation of the ore on the application of heat. This ore is mixed with a portion of the fuel and lime made use of in smelting, all of which are deposited upon the top of the smelting hearth, and are called hearth-ends. It is customary to remove the hearth-ends from time to time, and deposit them in a convenient place until the end of the year, or some shorter period, when they are washed to get rid of the earthy matter they may contain, and the metallic portion is roasted at a strong heat, until it begins to soften and cohere into lumps, and afterwards smelted in the ore-hearth, exactly in the same way as ore undergoing that operation for the first time, as already described. It is difficult to state what quantity of hearth-ends are produced by the smelting of a given quantity of ore, but in one instance the hearth-ends produced in smelting 9,751 bings, on being roasted and reduced in the ear-hearth, yielded of common lead 315 cwt., and the gray slags separated in this process gave, by treatment in the slag-hearth, 47 cwt. of slag lead; making the total quantity of lead 362 cwt., which is at the rate of 3 cwt. 2 qrs. 29 lbs. from the smelting of 100 bings of ore.

Slag-hearth.—The various slags obtained from the different operations of lead smelting are divided into two classes. Those which do not contain a sufficient amount of metal to pay for further treatment are thrown away as useless, whilst those in which the percentage of lead is sufficiently large are treated by the slag-hearth.

*1 bing = 8 cwt. 14 
fodder = 21 cwt. 14
description of apparatus which has been hitherto employed for the treatment of lead ores of low produce. This apparatus, although first employed in Spain, was invented by an Englishman (Mr. W. Groundry) who was employed in the reduction of rich slags in the neighborhood of Carthagena.

This furnace is circular, usually about 2 feet 4 inches, or 2 feet 6 inches in diameter, and is constructed of the best fire-bricks, so moulded as to fit together, and allow all the joints to follow the radii of the circle described by the brickwork. Its usual height is 8 feet 6 inches, and the thickness of the masonry invariably 9 inches. In this arrangement the breast is formed by a semi-circular plate of cast-iron, furnished with a lip for running off the slag, and has a longitudinal slot, in which is placed the tapping-hole.

On the top of this cylinder of brickwork, a box-shaped covering of masonry is supported by a cast-iron framing, resting on four pillars, and in this is placed the door for feeding the furnace, and the outlet by which the various products of combustion escape to the flues. The lower part of this hood is fitted closely to the body of the furnace, whilst its top is closed by an arch of 44-inch brickwork laid in fire-clay. The bottom is composed of a mixture of coke-dust and fire-clay, slightly moistened, and well beaten to the height of the top of the breast-pan, which stands nearly 3 feet above the level of the floor. Above the breast-pan is an arch, so turned as to form a sort of niche, 18 inches in width and rather more than 2 feet in height.

When the bottom has been solidly beaten, up to the required height, it is hollowed out so as to form an internal cavity, communicating freely with the breast-pan, which is filled with the same material and subsequently hollowed out to a depth slightly below the level of the internal cavity. The blast is supplied by three water tuyères, 5 inches in diameter at the smaller end, 6½ inches at the larger, and 10 inches in length. Into these the ore is introduced, which a current of air is supplied, by which mixtures of air and coke-dust, or coke-dust alone, are sent into the furnace, and in the process, the lead is volatilized. A few minutes only are sufficient to melt the lead, which, on being properly skimmed, is collected by the breast-pan, and then flows in a thin stream through the slag-ladle, and passes into the lead pot, which is kept hot. The hot lead now passes into a large lead-pot, by removing the clay-stopper of the tap-hole situated in the side of the breast-pan, and after being properly skimmed it is ladled into moulds. When in addition to lead, the ore treated likewise contains a certain portion of copper, this metal will be found in the form of a mass floating on the surface of the leaden bath. This, when sufficiently solidified, is removed, and after being roasted is operated on for the copper it contains.

The wagons in which the liquid slag runs off, are frequently made to traverse small railways, by which, when one mass has been removed, its place may readily be supplied by an empty wagon. When nearly cold the castings of the wagons are turned over and the blocks of slag easily made to drop out. In addition to the facility for transport obtained in this way, one of the great advantages obtained by this method of manipulation arises from the circumstance, that should the furnaces at any time run lead or matt, without its being detected by the smelter, the whole of it will be collected at the bottom of the block, from which, when cold, it may be readily detached.

In working these furnaces, care must be taken to prevent flame from appearing at the tunnel-head, since, provided the slags are sufficiently liquid, the cooler the apparatus is kept the less will be the loss of metal through volatilization. In addition to the greatest attention being paid to the working of the furnace, it is necessary, in order to obtain the best results, that all establishments in which this apparatus is employed should be provided with long and capacious flues, in which the condensation of the fumes takes place, previous to arriving at the chimney-shaft. These flues should be built at least three feet in width and six feet in height, so as readily to admit of being cleaned, and are often made of several thousand yards in length. The value of the fumes, so condensed, amounts to many hundreds, and in some instances thousands per annum.

This apparatus was advantageously worked in these furnaces, the ores should first be roasted, and subsequently agglomerated into masses, which, after being broken into fragments of about the size of the fist, and mixed with the various fluxes, are charged as before described.
LEAD.

In an establishment in which the average assay produce of the roasted ore for lead is 42 1/3ths, the furnace yield is 38 3/4ths, and the weight of coke employed to effect the reduction 22 per cent. of the roasted ore operated on. The mixture charged into the furnace, in this instance, is composed of 100 parts of roasted ore, 42 parts of slags from a previous operation, 8 parts of scrap iron, and 7 parts of limestone. Each furnace works off about seven tons of roasted ore in the course of 24 hours; the weight of slags run off is about double that of the lead obtained, and the matt removed from the surface of the pan is nearly 5 per cent. of the lead produced. The ores treated in this establishment consist of galena, much mixed with sathose iron, and are therefore somewhat refractory. A furnace of this kind requires for its construction about 1,000 segmental fire-bricks, and the same number of ordinary fire-bricks of second quality.
**Lead.**

Figs. 374, 375, 376, and 377 represent respectively a vertical section, an elevation, a ground plan, and a horizontal section of a Castilian furnace. The section (fig. 377) is on the line x x (fig. 375.) A is the body of the furnace, n, the bottom composed of a mixture of coke-dust and fire-clay; c c c, the tuyères; p, the rectangular covering of masonry; r e r, cast-iron pillars, r, the breast-pan; q, slot for tapping-hole; n, lip of breast-pan; i, feeding door; e, flue-hole; p, q, ground line.

Figs. 378, 379 are the slag-wagons, a being a movable case without a bottom, and b a strong cast-iron plate running on four wheels.

The desulphuration of the ores to be treated in these furnaces may be effected either by the aid of an ordinary reverberatory roasting furnace, or in heaps, or properly constructed kilns. The kilns best adapted for this purpose consist of rectangular chambers, having an arched roof, and provided with proper fluxes for the escape of the evolved gases, as well as a wide door for charging and withdrawing the ore to be operated on.

Each of these chambers is capable of containing from 25 to 30 tons of ore, and, in order to charge it, a layer of faggots and split wood is laid on the floor, and this, after having been covered by a layer of ore about two feet in thickness, is ignited, care being at the same time taken to close, by means of loose brick-work, the opening of the door to the same height. When this first layer has become sufficiently ignited, a fresh stratum of ore, mixed with a little coal or charcoal, is thrown upon it, and when this layer has in its turn become sufficiently heated, more ore is thrown on. In this way, more ore is from time to time added, until the kiln has become full, when the orifice of the doorway is closed by an iron plate, and the operation proceeds regularly and without further trouble until the greater portion has become eliminated.

This usually happens at the expiration of about four weeks from the time of first ignition, and the brick-work front is then removed, and the ores broken out, and, after being mixed with proper fluxes, passed through the blast furnace.

The proportion of wood necessary for the roasting of a ton of ore by this means, must necessarily depend on the composition of the minerals operated on; but with ores of the description above mentioned, and in a neighborhood where wood is moderately cheap, the desulphuration may be effected at a cost of about 5s. per ton.

**Calcining.**—The lead obtained by the various processes above described, generally contains a sufficient amount of silver to render its extraction of much importance; but, in addition to this, it is not unfrequently associated with antimony, tin, copper, and various other impurities, which require to be removed before the separation of the silver can be effected.

This operation consists in fusing the hard lead in a reverberatory furnace of peculiar construction, and allowing it to remain, when in a melted state, exposed to the oxidizing influences of the gases passing through the apparatus. By this treatment the antimony, copper, and other impurities become oxidized, and on rising to the surface of the metallic bath are skimmed off, and removed with an iron rake. The hearth of the furnace in which this operation is conducted consists of a large cast-iron pan, which may be 10 feet in length, 5 feet 6 inches in width, and 10 inches in depth. The fire-place, which is 1 foot 8 inches in width, has a length equal to the width of the pan, and is separated from it by a fire-bridge 2 feet in width. The height of the arch at the bridge end is 1 foot 4 inches above the edge of the pan, whilst at the outer extremity it is only about 8 inches.

The lead to be introduced into the pan is first fused in a large iron pot fixed in brick-work at the side of the furnace, and subsequently laded into it through an iron gutter.
adapted for that purpose. The length of time necessary for the purification of hard lead obviously depends on the nature and amount of the impurities which it contains; and, consequently, some varieties will be sufficiently improved at the expiration of twelve hours, whilst in other instances it is necessary to continue the operation during three or four weeks. The charge of hard lead varies from eight to eleven tons.

When the metal is thought to be in a fit state for tapping, a small portion taken out with a ladle, and poured into a mould used for this purpose is found on cooling to assume at the surface a peculiar crystalline appearance, which when once seen is readily again recognized. As soon as this appearance presents itself, an iron plug is withdrawn from the bottom of the pan, and the lead run off into an iron pan, from which it is subsequently lided into moulds.

The items of cost attending the calculation of one ton of hard Spanish lead in the north of England are about as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wages</td>
<td>1 11.2</td>
</tr>
<tr>
<td>Coals, 2-7 cwt.</td>
<td>0 4.7</td>
</tr>
<tr>
<td>Repairs, &amp;c.</td>
<td>0 0.5</td>
</tr>
</tbody>
</table>

The construction of a furnace of this description requires 5,000 common bricks, 3,500 fire-bricks, and 2 tons of fire-clay.

Figs. 380 and 381 represent an elevation and vertical section of the calcining furnace.

380

381

382

A is the fire-place; B, ash-pit; C, fire-bridge; D, cast-iron pan; E, flue; F F F, channels for allowing the escape of moisture; G, one of the working doors; H, spout for running off calcined metal. Fig. 382 represents the pan removed from the masonry, and shows a groove in the lip for the introduction of a sheet-iron dam, tightened with moistened bone-ash, for keeping in the fused metal.

In the more modern furnaces of this description, the corners are usually rounded to prevent breakage from expansion, whilst the tapping is effected by means of a hole through the bottom near one of the sides. This, when closed, is stopped by means of an iron plug kept in its place by a weighted lever.

Concentration of the silver.—This process is founded on the circumstance first noticed in the year 1829, by the late H. L. Pattinson of Newcastle-on-Tyne, that when lead containing silver is melted in a suitable vessel, afterwards slowly allowed to cool, and at the same kept constantly stirred, at a certain temperature near the melting point of lead,
LEAD.

Metallic crystals begin to form. These as rapidly as they are produced sink to the bottom, and on being removed are found to contain much less silver than the lead originally operated on. The still fluid portion, from which the crystals have been removed, will at the same time be proportionally enriched.

This operation is conducted in a series of 8 or 10 cast iron-pots, set in a row, with fireplaces beneath. These are each capable of containing about 6 tons of calcined lead; and on commencing an operation, that quantity of metal, containing we will suppose 20 oz. of silver per ton, is introduced into a pot (say p, \( \text{fig. 383} \)) about the centre of the series. This, when melted, is carefully skimmed with a perforated ladle, and the fire immediately withdrawn. The cooling of the metal is also frequently hastened by throwing water upon its surface, and whilst cooling it is kept constantly agitated by means of a long iron stirrer or slice. Crystals soon begin to make their appearance, and these as they accumulate and fall to the bottom are removed by means of a large perforated ladle, in which they are well shaken, and afterwards carried over to the next pot to the left of the workman. This operation goes on continually until about 4 tons of crystals have been taken out of the pot \( p \), and have been placed in pot \( q \), at which time the pot \( r \) may contain about 40 oz. of silver to the ton, whilst that in \( v \) will only yield 10 oz. The rich lead in \( v \) is then laded into the next pot \( a \), to the right of the workman, and the operation repeated in \( v \) on a fresh quantity of calcined lead.

In this way, calcined lead is constantly introduced, and the resulting poor lead passes continually to the left of the workman, whilst the rich is passing towards his right. Each pot in succession, when filled with lead of its proper produce for silver, is in its turn crystallized, the poor lead passing to the left of the workman, and the enriched lead to his right. By this method of treatment, it is evident that the crystals obtained from the pots to the left of the workman must gradually be deprived of their silver, whilst the rich lead passing to his right becomes continually richer.

The final result is, that at one end of the series, the poor lead contains very little silver, whilst at the other an exceedingly rich alloy of lead and silver is obtained.

The poor lead obtained by this process should never contain more than 12 dwts. of silver per ton, whilst the rich lead is frequently concentrated to 500 oz. to the ton. This rich lead is subsequently cupelled in the refining furnace.

The ladle employed for the removal of the crystals, when manual labor is made use of, is about 16 inches in diameter, and 5 inches in depth, but when cranes are used much larger ladies are easily managed. A form of crane has been invented which effects considerable economy of labor in this operation. When, during the operation of crystallization, the ladle becomes chilled, it is dipped in a small vessel containing lead of a higher temperature than that which is being worked, and known by the name of a temper-pot. The pot
containing the rich lead is generally called the No. 1 pot; in some establishments, however, the last pot in which the poor lead is crystallized obtains this appellation.

Figs. 383 and 384 represent a plan and elevation of a set of Pattinson's pots, arranged in the most approved way. α is the "market pot," from which the desilverized lead is laded out. β, γ, δ, ε, ζ, η, θ, and ι, are the working pots, whilst α', β', γ', δ', ε', ζ', η', and ι', are their respective fireplaces. The "temper-pots" α α α α, are employed for heating the ladles when they have become too much reduced in temperature. The figs. 385 and 386 are sections showing the manner of setting and the arrangement of the pots and flues. A, pot; b, main flue; c, ash pit.

The cost of crystallizing one ton of calcined Spanish lead, in the establishment quoted when treating of calcination, is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wages</td>
<td>9 54</td>
</tr>
<tr>
<td>Coals, 4 cwt.</td>
<td>0 84</td>
</tr>
<tr>
<td>Repairs</td>
<td>0 23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10 43</strong></td>
</tr>
</tbody>
</table>

The erection of nine six-ton pots requires 15,000 common bricks, 10,000 fire-bricks, 160 feet of quarles, 80 fire-clay blocks, and 5 tons of fire-clay.

In some establishments, ten-ton pots are employed, and where cranes are made use of they are found to be advantageous.

**Refining.**—The extraction of the silver contained in the rich lead is conducted in a cupel forming the bottom of a reverberatory furnace called a refinery.

In this operation the litharge produced, instead of being absorbed by the substance of the cupel, is run off in a fluid state, by means of a depression called a gate.

The size of the fire-place varies with the other dimensions of the furnace, but is usually nearly square, and in an apparatus of ordinary size may be about 2 feet + 2 feet 6 inches. This is separated from the body of the furnace by a fire-bridge 18 inches in breadth, so that the flame and heated air pass directly over the surface of the cupel, and from thence escape by means of two separate apertures into the main flues of the establishment. The cupel or test consists of an oval iron ring, about 5 inches in depth, its greatest diameter being 4 feet and its lesser nearly 3 feet. This frame, in order to better support the bottom of the cupel, is provided with cross-bars about 4½ inches wide, and one-half inch in thickness. In order to
make a test, this frame is beaten full of finely-powdered bone-ash, slightly moistened with water, containing a small quantity of pearl-ash in solution, which has the property of giving consistency to the cupel when heated.

The centre of the test, after the ring has been well filled with this mixture, and solidly beaten down, is scooped out with a small trowel, until the sides are left 2 inches in thickness at top, and 8 inches at the bottom, whilst the thickness of the sole itself is about 1 inch.

At the fore part or wide end of the test, the thickness of the border is increased to 6 inches, and a hole is then cut through the bottom, which communicates with the openings or gates by which the fluid litharge makes its escape.

The test, when thus prepared, is placed in the refinery furnace, of which it forms the bottom, and is wedged to its proper height against an iron ring firmly built into the masonry. When this furnace is first lighted, it is necessary to apply the heat very gradually, since if the test were too strongly heated before it became perfectly dry, it would be liable to crack.

As soon as the test has become thoroughly dry, it is heated to incipient redness, and is nearly filled with the rich lead to be operated on, which has been previously fused in an iron pot at the side of the furnace, and beneath which is a small grate where a fire is lighted.

The melted lead, when first introduced into the furnace, becomes covered with a grayish dross, but on further increasing the heat, the surface of the bath unevers, and ordinary litharge begins to make its appearance.

The blast is now turned on, and forces the litharge from the back of the test up to the breast, where it passes over the gate, and falls through the aperture between the bone-ash and the ring into a small cast-iron pot running on wheels. The air, which is supplied by a small ventilator, not only sweeps the litharge from the surface of the lead towards the breast, but also supplies the oxygen necessary for its formation.

In proportion as the surface of the lead becomes depressed by its constant oxidation, and the continual removal of the resulting litharge, more metal is added from the melting pot, so as to raise it to its former level, and in this manner the operation is continued until the lead in the bottom of the test has become so enriched as to render it necessary that it should be tapped. The contents of the test are now so far reduced in volume that the whole of the silver contained in the rich lead operated on remains in combination with a few hundred weight only of metal, and this is removed by carefully drilling a hole in the bone-ash forming the bottom of the test. The reason for the removal of the rich lead, is to prevent too large an amount of silver from being carried off in the litharge, which is found to be the case when lead containing a very large amount of that metal is operated on.

When the rich lead has been thus removed, the tapping-hole is again closed by a pellet of bone-ash, and another charge immediately introduced.

As soon as the whole of the rich lead has been subjected so repulsion, and has become thus further enriched, the argentiferous alloy is itself similarly treated, either in a fresh test, or in that employed for the concentration of the rich lead. The brightening of pure silver at the moment of the separation of the last traces of lead, indicates the precise period at which the operation should be terminated, and the blast is then turned off, and the fire removed from the grate. The silver is now allowed to set, and as soon as it has become hardened, the wedges are removed from beneath the test, which is placed on the floor of the establishment. When cold, the silver plate is detached from the test, and any adhering particles of bone-ash removed by the aid of a wire brush.

A test furnace of ordinary dimensions requires for its construction about 2,000 common bricks, 2,000 fire-bricks, and 1½ tons of fire-clay. A furnace of this kind will work off 4 pigs of lead per hour, and consume 4 cwt. of coal per ton of rich lead operated on.

* The cost of working a ton of rich lead in the neighborhood of Newcastle, containing on an average 400 oz. of silver per ton, is as follows: —

<table>
<thead>
<tr>
<th>Description</th>
<th>Rate per Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refiner's wages</td>
<td>4  2/1</td>
</tr>
<tr>
<td>Coals, 4 cwt.</td>
<td>0  6/8</td>
</tr>
<tr>
<td>Engine wages</td>
<td>1  7/9</td>
</tr>
<tr>
<td>Coals, 5 cwt.</td>
<td>0  8/7</td>
</tr>
<tr>
<td>Pearl-ash</td>
<td>0  3/5</td>
</tr>
<tr>
<td>Bone-ash, 17/3 lbs.</td>
<td>3 1/0</td>
</tr>
<tr>
<td>Repairs</td>
<td>0  5/0</td>
</tr>
</tbody>
</table>

Total                        | 10 10/1 |

Figs. 387, 388, and 389, represent an elevation, plan, and section of a refining furnace; A, fireplace; B, ash-pit; C, fire-bridge; D, test-ring, shown in its proper position; E, flues; F, point where blast enters; G, pig-holes.*

* Pig-holes are used for introducing the lead in cases in which it is not ladded into the test in a fused state.
Reducing.—The reduction to the metallic state of the litharge from the refinery, the pot dross, and the mixed metallic oxides from the calcining furnace, is effected in a reverberatory apparatus, somewhat resembling a smelting furnace, except that its dimensions are smaller, and the sole, instead of being lowest immediately below the middle door, gradually slopes from the fire-bridge to near the flue, where there is a depression in which is inserted an iron gutter, which constantly remains open, and from which the reduced metal flows continuously into an iron pot placed by the side of the furnace for its reception, whence it is subsequently laded into moulds.

The litharge, or pot dross, is intimately mixed with a quantity of small coal, and is
charged on that part of the hearth immediately before the fire-bridge. To prevent the fused oxide from attacking the bottom of the furnace, and also to provide a sort of hollow filter for the liquid metal, the sole is covered by a layer of bituminous coal.

The heat of the furnace quickly causes the ignition of this stratum, which is rapidly reduced to the state of a spongy cinder. The reducing gases present in the furnace, aided by the coal mixed with the charge itself, cause the reduction of the oxide, which, assuming the metallic form, flows through the interstices of the cinder, and ultimately finding its way into the depression at the extremity of the hearth, flows through the iron gutter into the external east-iron pot. The surface of the charge is frequently, during the process of elaboration, turned over with an iron rake, for the double purpose of exposing new surfaces to the action of the furnace, and also to allow the reduced lead to flow off more readily.

Fresh quantities of litharge or pot dross, with small coals, are from time to time thrown in, in proportion as that already charged disappears, and at the end of the shift, which usually extends over 12 hours, the floor of cinder is broken up, and after being mixed with the residual matters in the furnace, is withdrawn. A new floor of cinders is then introduced, and the operation commenced as before. A furnace of this kind, having a sole 8 feet in length and 7 feet in width, will afford, from litharge, about 5½ tons of lead in 24 hours.

The dross from the calcining pan, when treated in a furnace of this description, should be previously reduced to a state of fine division, and intimately mixed up with small coal and a soda-ash. In many cases, however, the calcined dross is treated in the smelting furnace. The hard lead obtained from this substance is again taken to the calcining furnace, for the purpose of being softened.

The expense of reducing one ton of litharge may be estimated as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wages</td>
<td>2</td>
<td>6 9</td>
</tr>
<tr>
<td>Coals, 3 cwt.</td>
<td>0</td>
<td>5 2</td>
</tr>
<tr>
<td>Repairs</td>
<td>0</td>
<td>1 6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3</td>
<td>0 8</td>
</tr>
</tbody>
</table>

In the establishment from which the foregoing data were obtained, the cost of shaft, delivered at the works, was only 2s. 11d. per ton, which is cheaper than fuel can be obtained in the majority of the lead-mills of this country. In North Wales the cost of small coal is generally about 4s., and at Bristol 5s. 6d. per ton.

Figs. 290 and 291 represent a vertical section and plan of a reducing furnace, A, fire-place; b, ash-pit; c, fire-bridge; r, hearth; x, working-door; z, iron spout for conducting the reduced metal into the lead-pot G, which is kept heated by means of a fire beneath.

The total cost of elaborating one ton of hard lead, containing 30 oz. of silver per ton, in a locality in which fuel is obtained at the low price above quoted, is nearly as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcining</td>
<td>0</td>
<td>2</td>
<td>4 4</td>
</tr>
<tr>
<td>Crystallizing</td>
<td>0</td>
<td>9</td>
<td>6 5</td>
</tr>
<tr>
<td>Refining</td>
<td>0</td>
<td>9</td>
<td>2 2</td>
</tr>
<tr>
<td>Reducing—pot dross and litharge</td>
<td>0</td>
<td>1</td>
<td>0 8</td>
</tr>
<tr>
<td>Calcined dross</td>
<td>0</td>
<td>0</td>
<td>8 0</td>
</tr>
<tr>
<td>Slags</td>
<td>0</td>
<td>0</td>
<td>5 0</td>
</tr>
<tr>
<td>Bone-ash, &amp;c.</td>
<td>0</td>
<td>0</td>
<td>7 0</td>
</tr>
<tr>
<td>Transport, &amp;c.</td>
<td>0</td>
<td>1</td>
<td>1 0</td>
</tr>
<tr>
<td>Management, taxes, and interest of plant</td>
<td>0</td>
<td>5</td>
<td>10 0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1</td>
<td>2</td>
<td>3 9</td>
</tr>
</tbody>
</table>

One hundred tons of hard lead treated gave:

<table>
<thead>
<tr>
<th>Item</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft lead</td>
<td>94 30</td>
</tr>
<tr>
<td>Black dross</td>
<td>3 7 2</td>
</tr>
<tr>
<td>Loss</td>
<td>1 3 8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100 0 0</td>
</tr>
</tbody>
</table>

On comparing the expense of each operation, as given in the foregoing abstract, with the amounts stated as the cost of each separate process, they will be found to be widely different; but it must be remembered that the whole of the substances elaborated are far from being subjected to the various treatments described.

In order therefore to give an idea of the relative proportions which are passed through
LEAD.

the several departments, I may state, that in an establishment in which the ores are treated in the Castilian furnace, the following were the results obtained:

One hundred parts of raw ore yield:

<table>
<thead>
<tr>
<th>Ore Type</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roasted ore</td>
<td>85</td>
</tr>
<tr>
<td>Hard lead</td>
<td>43</td>
</tr>
<tr>
<td>Soft &quot;</td>
<td>55</td>
</tr>
<tr>
<td>Rich &quot;</td>
<td>9</td>
</tr>
<tr>
<td>Dross and litharge re-treated</td>
<td>18\frac{1}{2}</td>
</tr>
</tbody>
</table>

It may be remarked, that for the treatment of ores of good produce, the reverberatory furnace and Scotch hearth are to be preferred, but for working minerals of a low percentage the blast furnace may generally be substituted with advantage. The slag-hearth, from the amount of fuel consumed and loss experienced, is a somewhat expensive apparatus, and might in many cases be advantageously exchanged for the Castilian furnace.

It is well known that the losses which take place in this branch of metallurgy are, from the volatility of the metal operated on, unusually large. In those establishments, however, in which due attention is paid to fluxes and a proper admixture of ores, as well as the condensation of the fumes, a great economy is effected.

In some instances, flues of above five miles in length have been constructed, and the most satisfactory results obtained. The attention of lead smelters is being daily more directed to the prevention of the loss of metal by volatilization, and those who have adopted the use of long flues have been, in all cases, quickly repaid for their outlay.

As an example of the great extent to which sublimation may take place on the scale employed in large smelting works, we may mention the lead works belonging to Mr. Beau-
LEAD ORES, ASSAY OF.

The ores of lead may be divided into two classes.

The first class comprehends all the ores of lead which contain neither sulphur nor arsenic, or in which they are present in small proportion only.

The second class comprises galena, together with all lead ores containing sulphur, arsenic, or their acids.

The lead ore of the first class is simple in composition, and has been reduced to a state of tranquility by having been mixed with 600 grains of carbonate of soda, and 40 to 60 grains of finely-powdered charcoal, according to the richness of the mineral operated on.

This is introduced into an earthen crucible, of such a size as to be more than one-half filled by the mixture, and on the top is placed a thin layer of common salt. The crucible is then placed in the furnace and gently heated, care being taken to moderate the heat so as to convert the mixture of ore and flux, which soon begins to swell and enter into fusion, may not swell up and flow over. If the action in the crucible becomes too strong, it must be checked by removal from the fire, or by a due regulation of the heat by means of a damper. When the action has subsided, the temperature is again raised for a few minutes, and the assay completed. During the process of reduction, the heat should not exceed dull redness; but in order to complete the operation, and render the slag sufficiently liquid, the temperature should be raised to bright redness.

When the contents have been reduced to a state of tranquility, the crucible must be removed from the fire and the assay either rapidly poured, or, after being tapped against some hard body to collect the lead in a single globule, be set to cool. When the operation has been successfully conducted, the cooled slag will present a smooth concrete surface, with a vitreous lustre. When cold, the crucible may be broken, and the button extracted. To remove from it the particles of adhering slag, it is hammered on an anvil, and afterwards rubbed with a hard brush.

Instead of employing carbonate of soda and powdered charcoal, the ore may be fused with \( \frac{1}{4} \) times its weight of black flux, and the mixture covered by a thin layer of borax. Good results are also obtained by mixing together 400 grains of ore with an equal weight of carbonate of soda and half that quantity of crude tartar. These ingredients, after being well incorporated, are placed in a crucible, and slightly covered by a layer of borax.
LEAD ORES, ASSAY OF.

Each of the foregoing methods yields good results, and affords slags retaining but a small proportion of lead.

Ores of the Second Class.—This class comprehends galena, which is the most common and abundant ore of lead, and also comprises sundry metallurgic products, as well as the sulicates, phosphates, and arseniates of lead.

1. Assay.—The assay of this ore is variously conducted; but one of the following methods is usually employed for commercial purposes.

Fusion with an alkaline flux.—This operation is conducted in an earthen crucible, which is to be kept uncovered until its contents are reduced to a state of perfect fusion.

The powdered ore, after being mixed with three times its weight of carbonate of soda and 10 per cent. of finely pulverized charcoal, is slowly heated in an ordinary assay furnace until the mixture has become perfectly liquid, when the pot is removed from the fire, and, after having been gently tapped, to collect any globules of metal held in suspension in the slag, is put aside to cool. When sufficiently cold, the crucible is broken, and a button of metallic lead will be found at the bottom: this must be cleansed and weighed.

In place of carbonate of soda, pearlash may be employed, or the fusion may be effected with black flux alone. When the last-named substance is used, a somewhat longer time is necessary for the complete fusion of the assay. Each 100 parts of pure galena will by this method afford from 74 to 76 parts of lead.

Some of the old assayers were in the habit of first driving off the sulphur by roasting, and afterwards reducing the resulting oxide with about its own weight of black flux.

This method, from the great fusibility of the compounds of lead, requires very careful management, and at best the results obtained are unsatisfactory. Pure galena by this method can rarely be made to yield more than 70 per cent. of lead.

Fusion with metallic iron.—Mix the ore to be assayed with twice its weight of carbonate of soda, and, after having placed it in an earthen crucible, of which it should occupy about one half the capacity, insert with their heads downward three or four temporary nails, and press the mixture firmly around them. On the top place a thin layer of borax, which should be again covered with a little common salt. The whole is now introduced into the furnace and gradually heated to redness; at the expiration of ten minutes the temperature is increased to bright redness, when the fluxes will be fused and present a perfectly smooth surface. When this has taken place, the pot is removed from the fire, and the nails are separately withdrawn by the use of a small pair of tongs, care being taken to well cleanse each in the fluid slag until free from adhering lead. When the nails have been thus removed, the pot is gently shaken, to collect the metal into one button, and laid aside to cool; after which it may be broken, and the button removed.

Instead of first allowing the slags to cool and then breaking the crucible, the assay may, if preferred, after the withdrawal of the nails, be poured into a mould.

Assay in an iron pot.—Instead of adding metallic iron to the mixture of ore and flux, it is generally better that the pot itself should be made of that metal.

For this purpose, a piece of half-inch plate-iron is turned up in the form of a crucible and carefully welded at the edges. The bottom is closed by a thick iron rivet, which is securely welded to the sides, and the whole then finished on a properly formed mandril. To make an assay in a crucible of this kind, it is first heated to dull redness, and, when sufficiently hot, the powdered ore, intimately mixed with its own weight of carbonate of soda, half its weight of pearlash, and a quarter of its weight of crude tartar, is introduced by means of a copper scoop. On the top of the whole is placed a thin layer of borax, whilst the crucible, which, for the ready introduction of the mixture, has been removed from the fire, is at once replaced. The heat is now raised to redness, the contents gradually becoming liquid and giving off large quantities of gas. At the expiration of from eight to ten minutes the mixture will be in a state of complete fusion; the pot is now partially removed from the fire, and its contents briskly stirred with a small iron rod. Any matter adhering to its sides is also scraped to the bottom of the pot, which, after being again placed in a hot part of the furnace, is heated during three or four minutes to bright redness.

The crucible is then seized by a strong pair of bent tongs, on that part of the edge which is opposite the lip, and its contents rapidly poured into a cast-iron mould. The sides of the pot are now carefully scraped down with a chisel-edge bar of bone, and the adhering particles of metallic lead added to the portion first obtained. When sufficiently cooled, the contents of the mould are easily removed, and the button of lead cleansed and weighed. By this process pure galena yields 84 per cent. of metallic lead, free from any injurious amount of iron, and perfectly ductile and malleable.

This method of assaying is that adopted in almost all lead-smelting establishments, and has the advantage of affording good results with all the ores belonging to the second class.

Assay in the iron dish.—In some of the mining districts of Wales, the assay of lead
ore is conducted in a manner somewhat different to that just described. Instead of fusing
the ore in an iron crucible with carbonate of soda, pearlash, tartar and borax, the fusion is
affected in a flat iron dish, without the admixture of any sort of flux.—J. A. P.

LEAD, OXICHLORIDE OF. A white pigment patented by Mr. Hugh Lee Pattinson
of Newcastle, which he prepares by precipitating a solution of chlorid of lead in hot
water with pure lime water, in equal measures; the mixture being made with agitation.
As the operation of mixing the lime water, and the solution of chlorid of lead, require
to be performed in an instantaneous manner, the patentee prefers to employ for this
purpose two tumbling boxes of about 16 feet cubic capacity, which are charged with the two
liquids, and simultaneously upset into a cistern in which oxichloride of lead is instantane-
ously formed, and from which the mixture flows into other cisterns, where the oxichloride
subsides. This white pigment consists of one atom of chlorid of lead and one atom
oxide of lead, with or without an atom of water.

LEATHER. (Cat; Fr.; Leder, Germ.; Leer, Dutch; Leder, Danish; Läder, Swedish; Cuoio, Italian; Cuero, Spanish; Кожа, Russian.) This substance consists of the skins of
animals chemically changed by the process called tanning. Throughout the civilized
world, and from the most ancient times, this substance has been employed by man for
a variety of purposes. Barbarous and savage tribes use the skins of beasts as skins;
 civilized man renders the same substance unalterable by the external agents which tend
to decompose it in its natural state, and by a variety of peculiar manipulations prepares
it for almost innumerable applications.

Although the preparation of this valuable substance in a rude manner has been known
from the most ancient times, it was not until the end of the last, and the beginning of
the present century (1800) that it began to be manufactured upon right principles, in
consequence of the researches of Macbride, Deyeux, Seguin, and Davy.

Skin may be converted into leather either with or without their hair; generally, how-
ever, the hair is removed.

The most important and costly kinds are comprised under sole leather and upper leather,
to which may be added harness leather, belts used in machinery, leather hose, &c.; but as
far as the tanner is concerned, these are comprehended almost entirely in the kinds known
as upper leather.

The active principle by which the skins of animals are prevented from putrefying, and
at the same time, under some modes of preparation, rendered comparatively impervious
to water, is called tannin, or tannic acid, a property found in the bark of the various species
of Quercus, but especially plentiful in the gall-nut. When obtained pure, as it may easily
be from the gall-nut, by chemical means, tannic acid appears as a slightly yellowish, almost
a colorless mass, readily soluble in water; it precipitates gelatin from solution, forming
what has been called tannoglobulin. Tannic acid also precipitates albumen and starch.
There can be little difficulty, after knowing the chemical combination just alluded to, in
understanding the peculiar and striking change produced on animal substance in the forma-
tion of leather. The hide or skin consists principally of gelatin, for which the vegetable
astringent tannin has an affinity, and the chemical union of these substances in the process
of tanning produces the useful article of which we are treating.

Before entering upon the various processes by which the changes are effected on the
animal fibre, it may not be uninteresting to speak of some of the principal astringents used
for the purpose of producing these effects.

Bark obtained from the oak-tree is the most valuable and the most extensively used
ingredient in tanning, and for a long time no other substance was used in England for the
purpose. In consequence of the demand having become very much greater than the supply,
and the consequent increase in the price of the article, it became necessary to investi-
gate its properties, in order, if possible, to furnish the required quantity of tanning matter
from other sources. Among other substitutes which were tried with some success in other
countries, may be mentioned beath, myrtle leaves, wild laurel leaves, birch tree bark, and
(according to the Penny Cyclopædia) in 1756 Oak sawdust was applied in England, and has
since been used in Germany for this purpose.

Investigation proved that the tanning power of oak bark consisted in a peculiar astringent
property, to which the name of tannin has been given, and this discovery suggested
that other bodies possessing this property would be suitable substitutes.

According to Sir H. Davy, the following proportions of tannin in the different substances
mentioned will be found:—"4 3/4 lbs. of oak bark are equal to 24 lbs. of galls, to 3 lbs. of
sumach, to 7/3 lbs. of bark of Leicester willow, to 11 lbs. of the bark of the Spanish chest-
nut, to 15 lbs. of elm bark, and to 21 lbs. of common willow bark."—Penny Cyclopædia.

Oak bark contains more tannin when cut in spring by four and a half times, than when
cut in winter; it is also more plentiful in young trees than in old ones. About 40,000
tons of oak bark are said to be imported into this country annually, from the Netherlands,
Germany, and ports in the Mediterranean. The quantity of English oak bark used we have
no means of ascertaining. It is prepared for use by grinding it to a coarse powder between
LEATHER, CURRYING OF.

cast-iron cylinders, and laid into the tan-pits alternately with the skins to be tanned. Sometimes, however, as will be hereafter noticed, an infusion of the bark in water is employed with better effect.

Mimosas.—The bark and pods of several kinds of Prosopis, the astringent properties of which have rendered them valuable in tanning, are known in commerce by this name. The Mimose are a division of the leguminous order of plants, which consists of a large number of species, the Acacia being the principal. The sensitive plants belong to this division. The proposition is found in India and South America; the genus consists both of shrubs and trees.

Valonia.—The oak which produces this acorn is the Quercus Aegilops, or great prickly cupped oak, (figs. 392, 393.) These are exported from the Morea and Levant; the husk contains abundance of tannin.

Catechu, or Terra Japonica, is the inspissated extract of the Acacia catechu. At the time the sap is most perfectly formed the bark of the plant is taken off, the tree is then felled, and the outer part removed; the heart of the tree, which is brown, is cut into pieces and boiled in water; when sufficiently boiled it is placed in the sun, and, subject to various manipulations, gradually dried. It is cut into square pieces, and much resembles a mass of earth in appearance; indeed, it was once considered to be such, hence the name Terra Japonica.

We give Sir H. Davy's analysis; the first numbers represent Bombay, the second Bengal catechu:

\[
\begin{array}{c|c|c|c|c|c}
\text{Tannin} & \text{Extractive} & \text{Mucilage} & \text{Impurities} \\
\hline
\end{array}
\]

This astringent is also obtained from the Uncaria Gambir.

Divinia is a leguminous plant of the genus Csesalpinia, C. coriaria. The legumes of this species are extremely astringent, and contain a very large quantity of tannic and gallic acid; they grow in a very peculiar manner, and become curiously curled as they arrive to perfection. The plant is a native of America, between the tropics. Fig. 394.

Scamach is a plant belonging to the genus Rhus; several of the species have astringent properties; Rhus coriariaus and Rhus coriaria are much used in tanning; the bark of the latter is said to be the only ingredient used in Turkey for the purpose of converting gelatin into leather. That used in this country is ground to a fine powder, and is extensively applied to the production of bright leather, both by tanners and curriers.

Many other vegetable products have been from time to time proposed, and to some extent adopted for the same end, but they need not be enumerated.

LEATHER, CURRYING OF. The currier's shop has no resemblance to the premises of the tanner, the tools and manipulations being quite different.

Within the last twenty or thirty years, many tanners have added the currying business
LEATHER CURRYING OF.

to their establishments, and many curriers have likewise commenced tanning; but in each case, an extension of premises is necessary, and the two departments are still separate. The advantages derivable from this arrangement are twofold,—first, a saving of time is effected, for as the tanned leather is sold by weight, it is required to be well dried before being disposed of to the currier—an operation which is not needed where the tanner carries on the currying also; and secondly, by the currier's art, the skins can be reduced to a comparatively uniform thickness previous to their being tanned, thus saving time and bark, used for tanning, and insuring a more equal distribution of tannin through the substance of the skin. In the following description, the business of currying will be considered as practised at the present time:—

The currier's shop or premises, to be convenient, should be spacious. A frequent, though not universal method, is to have the ground-floor appropriated to such operations as require the use of a large quantity of water. The place or apartment thus used, is called the scouring-house, and is commonly furnished with a number of vats or casks open at one end, in which the leather is placed for the purpose of soaking, and undergoing such treatment as will be hereafter described. In this apartment also is placed a large, flat, slate stone, called a scouring-stone, or, more consistently, the stone on which the leather is secured. This stone, which has its face perfectly flat and smooth, and which should measure 8 or 9 feet in length, by 4½ broad, forms a table, supported generally by masonry, but sometimes by a strong frame of wood, so constructed, that the water, which is freely used in scouring, may drain off on the opposite side from that on which the workman is engaged; an inclination of about three or four inches on the width of the table is sufficient for this purpose. Another piece of furniture very frequently found in, or on the same floor with the scouring-house, is a block of sandstone, in the form of a parallelepipedon, between 2 and 3 feet long, and 9 or 10 inches broad, the upper face of which is kept as near as possible a perfect plane; this stone is fixed at a convenient height on a strong trussel, and is called the rub-stone, because here the workman’s knives or sharpens his knives and other tools. In some large establishments where the premises and water are heated by steam, the scouring-house will be found with a service of pipe leading to the various vats, and the boiler, for generating the steam, may be conveniently placed in or near this part of the building.

The floor above the scouring-house, in the arrangement here laid down, is what is specially designated the shop. The furniture in this department consists of a beam, (fig. 395,) on which the leather is dried. It consists of a heavy block of wood, on which the workman stands, and into one end of which a stiff piece of wood is firmly mortised, at an angle of about 85°; this upright (so called) is about a foot wide, the height being greater or less, according to the height of the workman, each of whom has his beam adjusted to meet his convenience. On the front of the upright, a piece of deal is firmly screwed, to which is glued a piece of plate of lignes vitre, worked to perfect smoothness to agree with the edge of the knife used in the operation of shaving. It is of the greatest importance to the workman, to keep his skin from injury, that his knife and beam should be kept in good order. A table or tables, generally of mahogany, large planks of which are used for the purpose to avoid joints, may be said to form a necessary part of the furniture of this department. These tables are firmly fixed, to resist the pressure of the workman when using various tools; and as light is of the greatest consequence in the operations performed on them, they are usually placed so as to have windows in front of them. A high treading is frequently used, across which the leather is thrown, after undergoing any of the processes, while the currier subjects other pieces to the same operation.

Another part of the premises is termed the dressing-loft. In good buildings the dressing-loft is surrounded with weather-boards, constructed to be opened or closed as may be required. The use of this part being the drying of the leather, the ceiling is furnished with a number of rails or long pieces of wood, with hooks or nails on which to hang the leather for drying, and where steam is used for this purpose, the floor is traversed with pipes for heating the loft. Here also is a table, similar to that previously described; it should not be less than 7 or 8 feet long by 4½ broad, if possible, without joint, and with a smooth face. There are other subordinate departments, each furnished with a table similar to those described.

Of the tools used in currying, the knife stands first in importance, (fig. 396,) Here a and b are two handles; a is held in the left hand, and forms a powerful lever when the edge c is applied.
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to the leather. The blade of the currier's knife is peculiarly \textit{tempered}; it is composed of a plate of fine steel, strongly riveted between two plates of iron. This instrument is taken to the \textit{rub-stone}, and ground to a perfectly sharp edge by successively rubbing forward and backward; care being taken to keep the edge \textit{true}, that is, \textit{straight}. When this has been satisfactorily accomplished, it is still further rubbed on a fine Scotch or Welsh stone called a \textit{clearing-stone}, until the scratches of the \textit{rub-stone} disappear.

In this operation a fine thread or wire forms on the edges, for the knife has two edges (\textit{c} \textit{c}) which must be carefully got rid of; after which it is wiped dry, and the edges greased with tallow or oil. The workman then takes a strong steel, and placing himself on his knees, he fixes the knife with the straight handle \textit{b} against any firm body, and the cross handle \textit{a} between his knees; then holding the steel in both hands he carefully rubs it forward and backward the whole length of the edge. During this operation the knife is gradually raised by means of the handle \textit{a} until it is nearly perpendicular; by this means the edge is turned completely over. If the knife is not well tempered, the edge thus obtained will be irregular, or broken; in either of which cases it is of no use whatever.

To keep the instrument just described in proper order requires great skill on the part of the currier. The edge is so delicate and liable to injury that it cannot be used more than a minute or two without losing its keenness. To restore this, a very carefully prepared small steel is used, \textit{fig. 397}; the point of the steel is first run along the groove which is formed by turning the edge over, and the steel is then made to pass outside the edge. It is remarkable that a skillful hand can thus restore the efficiency of the knife, and keep it in work for hours without going for a new edge to the \textit{rub-stone}.

The other tools will be described as their uses are mentioned.

The first thing done by the currier is the soaking of the leather received from the tanner in water; the skin requires a thorough wetting, but not to saturation. In some cases the thicker parts are partially soaked before the immersion of the whole, and when from the nature of the skin this cannot be done, water is applied to the stout parts of the dipping; it is requisite that the whole should be as near as possible equally wet. In some

\begin{itemize}
\item \textbfit{instances the wetted leather is beaten, and sometimes a coarse graining-board (hereafter to be described) is used, to make it more supple previous to shaving it. The skin is then laid over the beam, (\textit{fig. 399},) and the rough fleshy portion is shaved off. This operation is}
\end{itemize}
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Generally called skiving. In all the operations at the beam, the leather is kept in its place by pressure of the knees or body of the workman from behind. In skiving, the right hand handle of the knife somewhat precedes the left, but in shaving, properly so called, the left hand precedes the right, fig. 400. In skiving, the knife is driven obliquely a few inches at a time; in shaving, it is driven with great force, not unfrequently from the top to the bottom of the beam; great skill is requisite in the performance of these operations, to guide the knife and to keep its edge. The carpenter's plane can be most completely regulated by the projection of the plane-iron from the wood, but the currier's knife admits of no such arrangement, and the unskilful currier is constantly liable to injure the leather by cutting through it, as well as by failing to produce a regular substance. The kind of skin, and the use for which it is designed, will regulate the work at the beam. In some cases, as in the calf-skin, it is skived and then shaved, or (as it is called) flattened at right angles to the skiving—in other kinds, as the cow-hide prepared for the upper leather of heavy shoes, after skiving it is shaved across, (i. e. nearly at right angles to the skiving,) and flattened by being again shaved in the same direction as the skiving. In some manufactories there are certain kinds of leather which are subjected to the operation called by curriers stoning, before flattening: this is done by forcibly driving the stock-stone (fig. 401) over the grain side of the leather, thereby stretching it and rendering the grain smooth. The flattening process is considerably facilitated by this stoning, and if the skin has been allowed slightly to harden by exposure to air, and the edge of the knife is fine, as it should be, the workman has but to strike the flat part of the knife over the leather after the shaving is performed, to produce a beautiful face to the flesh side of the skin. It will not be difficult to understand that a good hand is easily distinguished from an inferior one in this part of the business. With such nicety will a skilful workman set the edge of his knife, that although there seems nothing to guide him, he can take shaving after shaving from the hide, extending from the top to the bottom of the beam, thus rendering the leather extremely even in its substance.

After the process of shaving is completed, the leather is placed in water, where it remains until it is convenient to carry on the operation next required. It is to be observed, that in the condition in which leather is shaved, it cannot long be kept without becoming heated; when, however, it is put into water, it is safe from injury, and may be kept a very long time, provided the water be occasionally changed for a fresh, sweet supply; stale water is regarded as injurious for the skin to remain in.

Scouring is next proceeded with; the skin is taken out of the water, and laid on the scouring-stone. In respectable manufactories, it is usual first to scour on the flesh; this is done by passing a slicker smartly over the flesh side, by which the grain of the leather is brought into close contact with the scouring-stone, and, being in a wet condition, the air is easily excluded, so that the leather sticks to the stone. A plentiful supply of water is now applied, and a large brush, with stiff hairs, is rubbed over the flesh, or upper side. Portions of the surface, in a pulpy condition, come off with the scrubbing, and the skin presents a soft, whitened, pulpy appearance; the pores are rendered capable of containing more moisture, and, altogether, the leather is much benefited. The slicker is a plate of iron or steel, or for particular purposes, of brass or copper; it is about five inches long, and, like the stock-stone, is fixed in a stock, or handle, (fig. 402.) It is sharpened at the rub-stone, by grinding the plate perpendicularly, and then on either side, thus producing two edges, (or rather, right angles.) The edges thus produced are not of an order to cut the leather, but rather to scrape it. The slicker is not intended to remove irregularities in the leather, but its uses are various, and it may be considered a very important tool, as will hereafter appear.

In the process of tanning, the grain side of the hide or skin becomes covered with a whitish body, derived from the bark called bloom; this is more or less difficult to remove, according to the hardness or softness of the water used in tanning, and the peculiar treatment of the tanner. It is, however, the currier's business to remove it, which he effects thus:—In the case of leather, whose grain is tender, as cow-leather, which is manufactured from horse hides, the grain being kept uppermost, the leather is spread on the scouring-stone, and being plentifully supplied with water, is stretched by using the slicker, or a fine pebble, ground to the shape of the stock-stone the bloom; is thus loosened, and, at the same time, by making it adhere to the scouring-stone, the next operation is readily carried on, which consists in smartly brushing the grain with a stuff-haired brush, at the same time keeping a quantity of water on the surface, the slicker is again used to remove the water and
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loosened bloom, and the scouring is complete. In the scouring of calfskins, and cow or ox hides, the stock-stone is used to fix the leather, and a piece of pumice-stone, the face of which has been ground to smoothness, and afterwards cut in grooves, is then forcibly rubbed over the grain, in order to remove the bloom. In this, as in other operations on the scouring-stone, water is a necessary ingredient. The bloom being sufficiently loosened by the pumice-stone, the brush is used to scrub up the remaining dirt, which is then removed by the stock-stone or slicker. In harness leather, which is stont, and requires to be stretched as much as possible, the pumice-stone is seldom used, the stock-stone and scouring-orest, being lustily applied until the bloom is sufficiently removed. Ordinary manufacturers within the present (nineteenth) century, have considered the operations of the scouring-house complete at this point. The modern currier takes a different view, and not unfrequently detains his scoured property for days, and sometimes for weeks, in the scouring-house.

If the leather is imperfectly tanned, or it is required to be made of a bright color, there are other processes to be passed through. In these cases sumach (an evergreen shrub of the natural order Sumacaceae, genus Rhus, and from the bark of which all the leather made in Turker is said to be tanned) is infused in boiling water, and when cooled to a tepid state the leather is placed in it. After staying a sufficient time it is taken to the scouring-stone; if cordovan, it is slicked as dry as can be well accomplished on the flesh side; other leather is for the most part slicked in a similar way on the grain side. Saddle leather which is required to be of a bright color is still further placed in warm water slightly acidulated with sulphuric or oxalic acid, or both; here for a time it is kept in motion, then taken to the scouring-stone, it is washed with peculiar chemical lotions, according to the taste or knowledge of the workman; then again it is dipped in tepid sumach infusion, then slicked with a copper or brass slicker, (iron is liable to stain leather thus prepared,) and a thin coat of oil being applied to either side, it is removed to the drying-loft. Until within a very few years, much time and trouble were taken to produce very bright leather for the saddle; but of late, brown-colored leather has been adopted to a considerable extent, as it is less liable to become soured. Nearly all leather is placed a short time in the loft before further manipulations are carried on, in order to harden it slightly by drying.

In the drying-loft, or its immediate vicinity, the leather receives the dubbing (dubbing, probably) or stuff ing. The substance so called is composed of tallow brought to a soft plastic condition by being melted and mixed with cod-liver oil; occasionally sod (an oil made in preparing sheep-skins) is in very small quantities added to the mixture. This is laid upon the leather either with a soft-haired brush, or a mop made generally of rags. The leather is prepared for stuffing by wetting slightly such parts as have become too dry. It is then taken to the table previously described, which being slightly oiled, the process is carried on by placing the skin on the table in the manner most convenient for stretching it and making the surface smooth. In those kinds that have a rough wrinkled grain, the flesh side is placed next the table and the stock-stone is used very smartly to stretch and smooth the grain. A kind of clamp or holdfast, composed of two cheeks fastened with a screw, is sometimes used to prevent the leather from moving during this operation, but in general these are not required; the slicker is then applied to remove the marks left by the stock-stone, and a thin stuffing being spread over the grain, it is turned over, slicked on the flesh lightly, a coat of stuffing is spread over it, and it is hung up to dry. In those kinds which have to be blacked (or stained) on the grain, a little cod oil only is spread on the grain, and the slicker is applied on the flesh side most laboriously previous to stuffing. Much skill is required to give the requisite quantity of stuff (dubbing) to the leather without excess, excess being injurious, and the quantity required is further regulated by the freshness or otherwise of the leather, the tan-yard from which it comes, and the treatment it has received in the scouring-house.

When dry, the skins or hides are folded together, to remain until required. It is certain the leather improves by remaining some weeks in this condition. It should be observed that, in drying, the leather absorbs a large quantity of the oleaginous matter with which it is charged, and the unabsorbed portion forms a thick coating of hardened greasy matter on the flesh side.

Leather which has to be blackened on the flesh, (wax leather,) from this point, receives different treatment from graining leather. Wax leather is taken to the shop-table and softened with a graining-board. The skin is laid on the table and doubled, grain to grain, the graining-board, (fig. 404,) which is confined to the hand by a leather strap, (a a,) is driven for-
ward and drawn back alternately until a grain is raised on the leather, and it has attained the required suppleness. Observe, the graining-board is slightly rounded on the lower surface, and traversed by parallel grooves from side to side, which are coarser or finer, as occasion requires. The grease is next removed from the flesh by the slicker, and afterwards a sharp slicker is passed over the grain to remove grease or other accumulations from it. The next process is called whitening. The leather is laid over the boom, and a knife with an extremely fine edge is used to take a thin shaving from the flesh side; this is a point at which a currier's skill is tested. The knife used is one that has been very much worn, the quality of which has been tested to the utmost; and so extremely true is the edge expected, that not the slightest mark (scratch) is allowed to appear on the surface of the leather. Only a good workman can satisfactorily accomplish this. The slightest gravel in the flesh of the skin may break the edge of the knife in pieces, and it is not easy to rectify so serious a misfortune; besides, a poor workman may tear up the edge by seizing, an operation which ought to mend the mischief instead of provoking it.

A fine graining-board is next used to soften the leather; the sufferer parts being boarded both on the grain and flesh sides, and the operation being carried on in two or three directions, to insure both softness and regularity of grain. Boarding is performed by doubling the leather and driving the double part forward and drawing it backward by the graining-board.

The leather is now prepared for the waxer, and passes, consequently, into his hands. Waxing, in large establishments, is a branch considered separate from the general business, and is usually in the hands of a person who confines himself to this occupation alone. The skin is laid on a table, and the color rubbed into the flesh side with a brush. It is necessary to give the brush a kind of circular motion to insure the required blackness in the leather. The color is made by stirring a quantity of the best lampblack into cod-liver oil; sometimes a little dubbing is added, and in order to make it work smoothly so as not to clog the brush, some stale tan-water from the vats in the scouring-house is beaten up with the mixture until it combines therewith. The preparation of the color is an important affair, and requires a considerable amount of time and labor to render it such as the waxer desires.

A slick-stone, or glass, is next used; this tool is about the size and shape of the slicker, but instead of being ground like it, the edges are very carefully removed, so that while, from end to end, it preserves nearly a right line, it is circular across the edge. The stone (a fine pebble) is little used now, plate-glass being substituted for it. The use of the tool just described is to smooth the flesh after the operation by the coloring brush, thereby getting rid of any marks made on the surface.

The next step in waxing is what is called sizing. Size is prepared by boiling glue in water—the melted glue is diluted with water to the extent required—in some cases it is softened by mixing cod-liver oil with it in cooling. When cold, it is beaten up with various ingredients, according to the taste or experience of the waxer; the waxer then rubs the size into the colored side of the leather, and with a sponge, or, more generally, the fleshy part of his hand, smooths it off. When dry, the slick-stone, or glass, is again applied, thus producing a polish on the size; and a very thin coat of oil completes the work. In different manufactories different methods are pursued, but the above is convenient and satisfactory in almost all circumstances. It is now ready for the shoemaker.

Leather intended to be blacked on the grain, has been folded up when dry after stuffing. Some years ago it was the custom to stain these kinds of leather, while wet in the scouring-house, by spreading stale urine over it and then applying a solution of copperas, (sulphate of iron.) That method is now exploded. The dry skins or pieces of leather are laid on the shop-board: a brush is used to saturate the grain with urine, or as is now more common, a solution of soda in water, and a peculiar preparation of iron in solution is afterwards laid over it, which blackens the surface. It may be observed that in wax-leather a body of black is laid on, and rubbed into the flesh; in grain leather the black is a stain. After the blackening, it is necessary to rub a small quantity of oil or dubbing over the blackened surface, then turning the oiled grain towards the table, a sharp slicker is used on the flesh side; the leather sticks to the table by means of the oil, and the slicker is driven so smartly over it, that it is stretched on the table, at the same time that the grease is removed. It is quite an important point to take all the stretch out of the leather in this operation, after which it is turned over; the table is covered with a very thin coat of hard tallow, a roll of tallow being rubbed over the table, for the purpose of keeping the leather fastened to it. A doll slicker is used on the grain to remove remaining marks and wrinkles, or to smooth any coarse appearance on the grain; a sharp slicker removes all the grease, and a thin coat of weak size, made of glue dissolved in water, is spread over it, and the process, usually called seasoning, is completed. The next object is carefully to dry the seasoned leather, and in this state it may be stored without injury.

The next step is very similar to that described in the case of wax-leather, and called whitening:—it is then softened by means of a fine graining-board, or a board of the same shape and size covered with cork, the grain side is placed next the table, and the flesh
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doubled against the flesh, and thus driven forwards and backwards until the required degree of suppleness is obtained. The loose particles of flesh are brushed off, and a slicker carefully passed over the grain removes all marks of the last operation. If a sufficiency of stuff has not been applied in the drying-loft, the deficiency is remedied by a coat of tallow-dubbing now spread over the grain, and allowed to remain some hours. As the leather absorbs the oily matter, a hardened coat of grease has to be removed by the aid of the slicker. The leather is then sized, and a very thin coat of oil spread over the size completes the operation.

In the preparation of various kinds of leather, or of leather for particular purposes, the currier has particular appliances. Harness leather is considerably dryer than other kinds before stuffing, and is subjected to immense labor by the stock-stone and slicker, to procure a smooth grain. It is blackened when dry like other grain leather, but instead of the oiling and other processes described, the hardest tallow procurable is rubbed into it, stoned with a fine pebble, slicked, and tallow again rubbed into it by hand. When dry after this operation, the grease is slicked from the flesh side, and a repetition of the tallowing, stoning, and rubbing finishes the work.

Saddle leather, which is cut into comparatively small pieces, after hardening in the drying-loft, is passed through a very different process from any described previously. The skin of the hog is much used for certain parts of hackney saddles, and the bristles, when removed by the tanner, leave indentations, or even holes in the tanned skin. Probably it was deemed desirable to obtain some imitation for the parts of the saddle where the hog skin was not suitable. The skin of the dog-fish (Scyllium, Cuv.) to some extent supplied the imitation, having hard tubercles on its surface. At first the skin was laid on the leather, and lustily pressed into it by rubbing it with a pebble or plate of glass; at length a press was invented, and more recently various methods have been proposed to produce the best effect. We have here (fig. 405) a representation of one of these presses, which may stand

As a type of all others; a a are the feet into which the uprights are inserted; b b are the two uprights tied at the top by c; a similar cross-piece ties them a little above the feet; d is a leaf fastened with hinges, which closes upon e when the press is not in use; e e are screws which press on the iron plate, in which the axes of the roller f are inserted; these plates imbedded in the uprights b b have considerable play, so as to allow the rollers f h more or less pressure as the case may require. The dotted line i i', represents an iron bar or cylinder, supplied with a small cog-wheel at i', and a crank-handle f'; this is turned round by the hand, and the small cog-wheel acts on a larger one k, which is attached to the axis of the roller f; f is a solid roller of hard wood, such as lignum vitae; upon this
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cylinder is strongly glued the fish skin, previously alluded to; \( h \) is a cylindrical solid piece of wood covered with stout flannel; \( l \) is a piece of leather on which the leather to be pressed is placed; when all is adjusted, the piece to be pressed is placed on \( l \), the handle is moved slowly round, and the whole is carried between the rollers; the leather thus receives the imprint of the fish skin, and at the same time becomes extremely solid. After drying, this is fit for the saddler.

Of late years the currier has undertaken an office which was previously the business of the boot-maker—namely, the blocking of boot fronts. This is performed by the instrument represented by fig. 406. The leather is first dressed, as previously described, up to the 406 point of being ready for whitening. The fronts are then cut, (fig. 406 a,) and when folded or doubled appear as fig. 406 b. 1' 1', 1 1', is a strong framework; 2, represents a pair of cheeks, strongly fastened in the frame, and regulated as to distance by a screw; these cheeks are lined with zinc; 3 is a strong plate of metal, the angle at 3 corresponding exactly with the angle of the cheeks; the ends of this plate are fixed in movable plates passing down the columns 1' 1'; 4 is a handle by which the instrument is worked, and which by cog-wheels acting on the movable plates brings 3 downwards. The front, \( a \), is laid, after a thorough soaking in water, over the cheeks 2, the handle being turned, 3 comes down upon the front, and forces it through the small opening between the cheeks, and when brought out below the cheeks, it has the appearance here given, (fig. 406 c.) The plate 3 having carried the front between the cheeks, is removed, (below,) and the weight 5 assists in bringing the perpendicular movable plates to their place, when 3 is again put in position; and thus the operation is rapidly carried on. After this the fronts are regularly placed on a
block, being forced into position by an instrument called the founder, (fig. 407,) and tacked to their place; after this they are slightly oiled and dried. Some ingenious methods have been adopted for softening the fronts, so as not to disturb the blocking. They are whitened on a very sloping beam, (fig. 408,) which enables the workman to hold them better than he could on the common beam. They are again blocked by the waxer, and when these processes are carefully performed, much trouble is saved to the boot-maker. Of course, in a manufactory many appliances are found which are not here mentioned; the general idea, however, may be easily gathered from this description. The work is dirty and very laborious, requiring great skill and experience, and consequently good workmen have generally commanded better wages than other mechanics.

Hides intended for covering coaches are shaved as thin as shoe hides, and blacked on the grain.—H. M.

LEATHER, VEGETABLE. Under this name a new material, composed of india-rubber spread upon linen, has been introduced. Of this the Mechanics' Magazine writes:—

"Having seen some specimens of these leathers, as well as various articles of utility manufactured therewith, we have been induced to pay the extensive works of Messrs. Spill & Co., the eminent Government contractors on Stepney-green, a visit, in order to cull sufficient to place upon record the present position of artificial as a substitute for real leather. The face and general character of the vegetable leather resemble the natural product so closely, that
it is only by actual examination that the difference can be determined. This is more particularly the case in that description which is made for bookbinding, the covering of library tables, and like purposes. Amongst other advantages it possesses over leather proper, may be mentioned, that however thin the imitation is, it will not tear without considerable force is exercised; that it resists all damp, and that moisture may be left upon it for any period without injury; consequently, it does not sodden or cockle, is always dry, and its polish is rather increased than diminished by friction. Add to these facts, that any attempt to scratch or raise its surface with the nail, or by contact with any ordinary substance, will not abrade it, and enough will have been said to justify its entering the list against an article of daily use, which less of late years been deemed far from sufficient for the demand, and has consequently risen in price to the manifest loss and injury of every class of the community. We believe that the largest entire piece of real leather that can be cut from a bullock's hide, is not more than 7 feet by 5 feet, and this includes the stomach and other inferior parts. Vegetable leather, on the contrary, is now produced 50 yards in length, and 13 yards wide, every portion being of equal and of any required thickness, and the smallest portion is convertible. We were agreeably disappointed, however, to find that instead of vegetable leather being a discovery requiring the aid of ourselves and contemporaries, it was, although so young, an active agent in the fabrication of numerous articles of daily requirement, and that it had already become the subject of large, indeed we may say enormous, contracts. Caoutchouc and naphtha are used in its manufacture; but by a process known to the senior of the firm, who is himself an accomplished chemist, all odor is removed from the naphtha, and the smell of vegetable leather is rendered thereby less in strength, if any thing, than that of leather. The principal objects to which it is at present applied, although it is obvious it will take a wider range of usefulness than leather itself, are carriage and horse aprons, antigropes, soldiers' belts, buckets which pack flat, harness of every description, bookbinding, &c. For the latter, its toughness, washable quality, and resistance to stains, render it remarkably fitted. Its thickness, which may be carried to any extent, is obtained by additional backings of linen, &c., cemented with the caoutchouc, and its strength is something marvellous, while in the all-important commercial view, it is but one-third the price of leather. Many of the articles we were shown possessed the appearance of much elegance and finish; but it was curious to observe, that although most of them could be made without a stitch, and within the factory itself, a deference to the feelings of the workmen in the several trades has been shown by the firm, and the material is given out as ordinary leather, to undergo the process of the needle, which it submits to with a greater facility than its original prototype."

LENS. (Lens, Fr.; Linsegläser, Germ.) Lenses are transparent bodies, usually made of glass, which, by their curvature either concentrate or disperse the rays of light. Lenses are of the following kinds—Double convex, having the same or a different degree of convexity on either side. Plano-convex, having one plane and one convex surface. Convexo-concave, having one concave and one convex side, commonly called meniscus lenses. Plano-concave, having one plane surface and one concave one; and the double concave lens.

The first three, which are thicker in the middle than at the edge, are converging lenses, because they occasion the rays of light to converge in passing through them. The others, which are thicker at the edges than in the middle, and therefore cause the pencils of light refracted through them to diverge, are called diverging lenses.

For the most complete examination of the laws regulating the construction of lenses, and the action of these on the rays of light, we must refer the reader to Sir John Herschell's admirable treatise on Light in the Encyclopaedia Metropolitana. In this work we have only to deal with the mode of manufacturing the ordinary varieties. The spherical surfaces are produced by grinding them in counterpart tools, or discs of metal, prepared to the same curvature as the lenses. For the formation of the grinding tools, a concave and a convex template are first made to the radius of the curvature of the required lens. The templates of large radius are sometimes cut out of crown glasses. More usually the templates are made out of sheet brass; the templates of long radii are cut with a strong radius bar and cutter, and those of only a few inches radius are cut in the turning lathe. The brass concave and convex gauges are cut at separate operations, as it is necessary to adjust the radius to compensate for the thickness of the cutter, and the brass templates are not usually corrected by grinding, as practically it is found more convenient to fit the tools themselves together. The templates having been made of the required radius, are used for the preparation of the grinding and polishing tools, which for concave lenses consist of a concave rough grinding tool of cast iron called a shell.

A pair of brass tools is, however, the most important part of the apparatus. One of these is concave and the other convex; made exactly to the curvature of the templates, and to fit each other as accurately as possible. The concave tool is used as the grinder for correcting the curvature of the lenses after they have been roughly curved in the concave shell, and the convex tool is employed for producing and maintaining the true form of the
concentric grinding tool itself, and also that of the polisher. These polishers are adjusted with great accuracy. The concentric tool is placed upon the convex, and they are first rubbed together dry, so that by the heightened parts the inequalities may be distinguished; they are then ground true, first by means of emery and water, and then with dry emery.

The following figure (409) represents those tools, which are fitted with screws at the back so that they can be fixed upon pillars in connection with the machinery for giving motion to them.

By grinding with sundry niceties of motion which are required to produce the best effect, such as the production of motion which shall resemble as nearly as possible the kind of stroke which would be given by the hand, these tools are eventually brought to true spherical figures which fit each other exactly.

The glasses for lenses being selected of suitable quality, they are brought to a circular form by means of flat pliers called shanks. The pressure of the pliers, applied near the edges of the glass, causes it to crumble away in small fragments, and this process, which is called shaving or nibbling, is continued until the glasses made are made circular, and of a little larger diameter than the finished size of the lenses.

A cement is made by mixing wood ashes with melted pitch. Some nicety is required in the adjustment of the proportion, since the cement must not be too adhesive, nor must it be too hard or too brittle: generally about 4 lbs. of wood ashes to 14 lbs. of pitch are employed. This when melted is poured on one side of the glasses to be ground, in small quantities at a time, until a sufficient quantity adheres to the back of the lens to form a handle. The glass is rough ground by rubbing it within the spherical shell. The glass is rubbed with large circular strokes, and the shell is usually placed within a shallow tray to catch the loose emery or polishing powder which may be employed. When one side is rough ground in this way, the glass is warmed to detach it from the hindle, which is transferred to the other side and the operation repeated. When both sides are thus rudely formed, the lenses are cemented upon a runner. The best object-glasses for telescopes are ground and polished singly, while as many as four dozen of common spectacle-glasses are ground and polished together. When many are thus fixed on one runner, the number must be such as will admit of their being arranged symmetrically around a central lens, as 7, 18, or 21; or sometimes 4 form the nucleus, and then the numbers run 14, 30.

Lenses of ordinary quality are usually ground true and polished 7 at a time. This runner, with its lenses attached, is shown in fig. 410.

The cement at the back of the lenses is first flattened with a heated iron. The cast-iron runner is heated just sufficiently to melt the cement, and carefully placed upon the cemented backs of the lenses. As soon as the cement is sufficiently softened to adhere firmly to the runner, it is cooled with a wet sponge, as the cement must only be so far fused as to fill up the spaces nearly, but not quite, level with the surface of the lenses. The block of lenses is now mounted upon a post, and ground with the concentric brass tool. (Fig. 409,) motion being given to it either by the hand or by machinery similar to the sweeping motion already named. As the grinding proceeds, the fineness of the emery powder employed is increased, until in the last operation it is sufficiently fine to produce a semi-polished surface. This grinding being completed successfully, the lenses have to be polished. The polisher is made by warming a cast-iron shell and coating it uniformly about one-quarter of an inch thick with melted cement. A piece of thick woollen cloth is cut to the size of the polisher and secured to it, and pressed into form by working the brass tool within it. When this is properly adjusted it is covered with very finely divided putty powder, sprinkled with a little water, and the powder worked into the pores of the cloth with the brass convex tool. Repeated supplies of putty powder are put on the polisher until it is made quite level, and it is worked smooth with the tool. Many hours are expended in the proper preparation of a polisher. When completed it is placed upon the block of lenses still fixed to the post, and worked with wide and narrow elliptical strokes. Where a very large number of glasses are ground or polished at the same time, this peculiar motion is imitated by the eccentric movement of a lever attached to the revolving shaft. In the processes of grinding and polishing, other materials besides emery and putty powder are sometimes employed, such as whet, an earthy oxide of iron, the finer kinds of which are much employed in the large lens manufactory at Sheffield.

Much more might be said on the subject of grinding and polishing lenses, but it is one of those processes of manufacture which scarcely come within the limits of the present work. Still it was thought to be of sufficient importance to receive some general notice. The grinding and polishing of the finer varieties of lenses for telescopes, microscopes, and the like, require extremely nice manipulation. The best account of the processes and of the instruments used is one by the late Andrew Ross, in the fifty-third volume of
the Transactions of the Society of Arts. In Holtzoffe's Mechanical Manipulation there is also some very excellent practical information.

LIGHT. (Lumière, Fr.; Licht, Germ.) The operation of light as an agent in the arts or manufacturers has scarcely yet received attention. Sufficient evidence has, however, been collected to show that it is of the utmost importance in producing many of the remarkable changes in bodies which are desired in some cases as the result, but which, in others, are to be, if possible, avoided.

There is a very general misconception as to the power or principle to which certain phenomena, the result of exposure to sunshine, are to be referred. In general light is regarded as the principle in action, whereas frequently it has nothing whatever to do with the change. A few words, therefore, in explanation are necessary. The solar rays commonly spoken of as light contains in addition to its luminous power, calorific power, chemical power, and in all probability electrical power. These phenomena can be separated one from the other, and individually studied. All the photographic phenomena are dependent upon the chemical (actinic) power. Many of the peculiar changes which are effected in organic bodies are evidently due to light, and the phenomena which depend entirely on heat are well known.

Herschel has directed attention to some of the most striking phenomena of light, especially its action upon vegetable colors. As these have direct reference to the permanence of dyes, they are deserving of great attention. The following quotation from Sir John Herschel's paper "On the Chemical Action of the Rays of the Solar Spectrum, etc." will explain his views and give the character of the phenomena which he has studied. He writes:

"The evidence we have obtained by the foregoing experiments of the existence of chemical actions of very different and to a certain extent opposite characters at the opposite extremities (or rather, as we ought to express it, in the opposite regions) of the spectrum, will naturally give rise to many interesting speculations and conclusions, of which those I am about to state will probably not be regarded as among the least so. We all know that colors of vegetable origin are usually considered to be destroyed and whitened by the continual action of light. The process, however, is too slow to be made the subject of any satisfactory series of experiments, and, in consequence, this subject, so interesting to the painter, the dyer, and the general artist, has been allowed to remain uninvestigated. As soon, however, as these evidences of a counterbalance of mutually opposing actions, in the elements of which the solar light consists, offered themselves to view, it occurred to me, as a reasonable subject of inquiry, whether this slow destruction of vegetable tints might not be due to the feeble amount of residual action outstanding after imperfect mutual compensation, in the ordinary way in which such colors are presented to light, i.e. to mixed rays. It appeared, therefore, to merit inquiry, whether such colors, subjected to the uncompensated action of the elementary rays of the spectrum, might not undergo changes differing both in kind and in degree which mixed light produces on them, and might not, moreover, by such changes indicate chemical properties in the rays themselves hitherto unknown.

"One of the most intense and beautiful of the vegetable blues is that yielded by the blue petals of the dark velvety varieties of the common heartsease (Viola tricolor). It is best extracted by alcohol. The alcoholic tincture so obtained, after a few days' keeping in a stoppered phial, loses its fine blue color, and changes to a pallid brownish red, like that of port wine discolored by age.

"When spread on paper it hardly tinges it at first, and might be supposed to have lost all coloring virtue, but that a few drops of very dilute sulphuric acid sprinkled over it, indicate by the beautiful and intense rose color developed where they fall, the continued existence of the coloring principle. As the paper so moistened with the tincture dries, however, the original blue color begins to appear, and when quite dry is full and rich. The tincture by long keeping loses this quality, and does not seem capable of being restored. But the paper preserves its color well, and is even rather remarkable among vegetable colors for its permanence in the dark or in common daylight.

"A paper so tinged of a very fine and full blue color, was exposed to the solar spectrum concentrated, as usual, (October 11, 1852,) by a prism and lens; a water-prism, however, was used in the experiment, to command as large an area of sunbeam as possible. The sun was poor and desultory; nevertheless in half an hour there was an evident commencement of whitening from the fiducial yellow ray to the mean red. In two hours and a half, the sunshine continuing very much interrupted by clouds, the effect was marked by a considerable white patch extending from the extreme red to the end of the violet ray, but not traceable beyond that limit. Its commencement and termination were, however, very feeble, graduating off insensibly; but at the maximum, which occurred a little below the fiducial point, (corresponding nearly with the orange rays of the luminous spectrum,) the blue color was completely discharged. Beyond the violet there was no indication of increase of color, or of any other action. I do not find that this paper is discolored by mere radiant heat unaccompanied with light."
Dr. George Wilson of Edinburgh made some exceedingly interesting experiments on the influence of sunlight over the action of the dry gases on organic colors. The results arrived at were communicated to the British Association, and an abstract of the communication is published in their transactions. The experiments were on chlorine, sulphurous acid, sulphuretted hydrogen, carbonic acid, and a mixture of sulphurous and carbonic acid, oxygen, hydrogen, and nitrogen, on organic coloring matters. "I have ascertained," says Dr. George Wilson, "the action of the gases mentioned already on vegetable coloring matters, so arranged that both coloring matter and gas should be as dry as possible, the aim of the inquiry being to elucidate the theory of bleaching, by accounting for the action of dry chlorine upon dry colors. In the course of this inquiry, I ascertained that in darkness dry chlorine may be kept for three years in contact with colors without bleaching them, although when moist it destroys their tints in a few seconds, (see BLEACHING;) and I thought it desirable to ascertain whether dry chlorine was equally powerless as a bleacher when assisted by sunlight. The general result of the inquiry was, that a few weeks sufficed for the bleaching of a body by chlorine in sunlight, where months, I may even say years, would not avail in darkness. The form of the experiment was as follows:—Four tubes were connected together so as to form a continuous canal, through which a current of gas could be sent. Each tube contained a small glass rod on which seven pieces of differently colored papers were spiked. It is not necessary here to state the colors employed, suffice it to say, that all the tubes thus contained seven different colored papers, of different origins, and easily distinguishable by the eye. They were arranged in the same order in each tube, and were prepared as nearly as possible of the same slend. These papers were carefully deprived of every trace of moisture by a current of very dry air. The tubes were then filled with the gas, also dried, on which the experiment was to be made. One tube of each series was kept in darkness, two others were exposed in a western aspect behind glass, and the other was turned to the south in the open air.

The results were as follows:—In the dark chlorine tube the colors were very little altered, and would probably have been altered less had not the tube been frequently exposed to light for the sake of examination. In the western tube, the original gray and green wallflower papers became of a bright crimson, the blue litmus bright red, and the brown rhubarb yellow. The whole of the chlorine had apparently entered into combination with the coloring matters, for the yellow tint of the gas had totally disappeared. In the southern tube the color of the chlorine could still be seen, the reddening action was less decided, and the bleaching action was more powerfully evinced. The general result was that the action of sunlight is less uniform than might have been expected in increasing the bleaching power of chlorine, or while some tints rapidly disappeared under its action assisted by light, other colors remained, in apparently the very same circumstances, unaffected.

Sulphurous acid, if thoroughly dried, may be kept for months in contact with dry colors without altering them; under the influence of sunlight it however recovers to some extent its bleaching power.

Sulphuretted hydrogen acts as a weak acid, and readily as a bleacher when moist, and becomes inactive in both respects if made dry and kept in darkness. With the assistance of sunlight it recovers in an incomprehensible degree its bleaching power.

Oxygen is a well-known bleaching agent, but when dry its action upon coloring matter in the dark is extremely slow. In sunlight, however, it recovers its bleaching power.

Carbolic acid, when dry in darkness, loses all power on coloring matter, but a faint bleaching action is exerted by it under exposure to sunlight.

Hydrogen is without any action when dry upon colors, but it acquires a slight decolorizing power when exposed to sunshine.

"The general result," concludes Dr. George Wilson, "of this inquiry, so far as it has yet proceeded, is, that the bleaching gases, viz., chlorine, sulphurous acid, sulphuretted hydrogen, and oxygen, lose nearly all their bleaching power if dry and in darkness, but all recover it, and chlorine in a most marked degree, by exposure to sunlight."

All these experiments appear to show that the action of the solar rays on vegetable colors is dependent upon the power possessed by one set of rays to aid in the oxidation or chemical changes of the organic compound constituting the coloring matter. The whole matter requires careful investigation.

It is a proved fact, that coloring matters, either from the mineral or the vegetable kingdom, are much brighter when they are precipitated from their solutions in bright sunshine, than if precipitated on a cloudy day or in the dark. It must not be supposed that all the changes observed are due to chemical action; there can be no doubt but many are purely physical phenomena, that is, the result of molecular change, without any chemical disturbance.

LIGHT-HOUSE. The importance of lights of great power and of a distinguishable character around our coasts is admitted by all. One of the noblest efforts of humanity
is certainly the construction of those guides to the mariners upon rocks which exist in the tracks of ships, or upon dangerous shores and the mouths of harbors. This is not the place to enter largely upon any special description of the lights which are adopted around our shores; a brief account only will be given of some of the more remarkable principles which have been introduced of late years by the Trinity Board.

The early light-houses appear to have been illuminated by coal or wood fires contained in "chauiers." The Isle of Man light was of this kind until 1816. The first decided improvement was made by Argand, in 1784, who invented a lamp with a circular wick, the flame being supplied by an external and internal current of air. To make these lamps more effective for light-house illumination, and to prevent the ray of light escaping on all sides, a reflector was added in 1780 by M. Lenoir; this threw the light forward in parallel rays towards such points of the horizon as would be useful to the mariner. Good reflectors increase the luminous effect of a lamp about 400 times; this is the "catoptric" system of lighting. When reflectors are used, there is a certain quantity of light lost, and the "dioptric" or refracting system, invented by the late M. Augustin Fresnel in 1822, is designed to obviate this effect to some extent. The "catadioptric" system is a still further improvement, and acts both by refraction and reflection. Light of the first order have an interior radius or focal distance of 35-22 inches, and are lighted by a lamp of four concentric wicks, consuming 570 gallons of oil per annum.

The appearance of light called short eclipses has hitherto been obtained by the following arrangement:—

An apparatus for a fixed light being provided, composed of a central cylinder and two zones of catadioptric rings forming a cupola and lower part, a certain number of lenses are arranged at equal distances from each other, placed upon an exterior movable frame making its revolution around the apparatus in a given period. These lenses, composed of vertical prisms, are of the same altitude as the cylinder, and the radius of their curves is in opposite directions to those of the cylinder, in such a manner that at their passage they converge into a parallel pencil of light, all the diverging rays emitted horizontally from the cylinder, producing a brilliant effect, like that obtained by the use of annular lenses at the revolving light-houses.

Before proceeding with the description of the lenses, the following notices may be of interest:—

The Eddystone Light-house, 9½ miles from the Rame Head, on the coast of Cornwall, was erected of timber by Winstanley in 1696–98, and was washed away in 1703. It was rebuilt by Redyard in 1706, and destroyed by fire in 1755. The present edifice was erected by Smeaton 1755–59. Tallow candles were used in the first instance for the lights; but in 1807 Argand lamps, with paraboloidal reflectors of silvered copper, were substituted.

The Skerryvore Rocks, about 12 miles southwest of Tyree on the coast of Argyllshire, lying in the track of the shipping of Liverpool and of the Clyde had long been regarded with dread by the mariners frequenting those seas. The extreme difficulty of the approaches to the rocky and broken coast of the island of Mull had alone deterred the commissioners of northern lights from the attempt to place a light upon this dangerous spot; but in 1834 they caused the reef to be surveyed, and in 1836 Mr. Alan Stephenson, their engineer, inheriting his father's energy and scientific skill, commenced his operations upon a site from which "nothing could be seen for miles around but while foaming breakers, and nothing could be heard but the howling of the winds and the lashing of the waves." His design was an adaptation of Smeaton's tower of the Eddystone to the peculiar situation, a circumstance with which he had to contend. He established a circular base 42 feet in diameter, rising in a solid mass of granite or granite, but diminishing in diameter to the height of 26 feet, and presenting an even concave surface all around to the action of the waves. Immediately above this level the walls are 9½ feet thick, diminishing in thickness as the tower rises to its highest elevation, where the walls are reduced to two feet in thickness, and the diameter to 16 feet. The tower is built of granite from the islands of Tyree and Mull, and its height from the base is 138 feet 8 inches. In the intervals left by the thickness of the walls are the stairs, a space for the necessary supply of stores, and a not uncomfortable habitation for three attendants. The rest of the establishment, stores, &c., are kept at the depot in the island of Tyree. The light of the Skerryvore is revolving, and is produced by the revolution of eight annular lenses around a central lamp, and belongs to the first order of dioptric lights in the system of Fresnel, and may be seen from a vessel's deck at a distance of 18 miles.—Lord de Mauley, Juror's Report, Great Exhibition, 1851.

Some of the lenticular arrangements must now claim attention. Large lenses, or any large masses of glass, are liable to strain, which by dispersing, occasion a loss of much light.

In order to improve a solid lens formed of one piece of glass whose section is \( \lambda \), \( m \), \( p \), \( n \), \( v \), \( r \), \( n \), \( c \), \( \lambda \), Buffon proposed to cut out all the glass left white in the figure,
(411) namely, the portions between \( m p \) and \( n o \), and between \( n o \) and the left-hand surface of \( D E \). A lens thus constructed would be incomparably superior to a solid one, but such a process we conceive to be impracticable on a large scale, from the extreme difficulty of polishing the surfaces \( A B, p, c, n, E F \), and the left-hand surface of \( D E \); and even if it were practical the greatest imperfections of the glass might happen to occur in the parts which are left. In order to remove these imperfections and to construct lenses of any size," says Sir David Brewster, "I proposed in 1811 to build them up of separate zones or rings, each of which rings was again to be composed of separate segments, as shown in the front view of the lens in fig. 412. This lens is composed of one central lens \( A B C D \), corresponding with its section \( p, e \), in fig. 411; of a middle ring \( G E F I \), corresponding to \( C D E F \), and consisting of 4 segments; and another ring \( X P R T \), corresponding to \( A C F E \), and consisting of 8 segments. The preceding construction obviously puts it in our power to execute those lenses to which I have given the name of polygonal lenses, of pure flint glass free from veins; but it possesses another great advantage, namely, that of enabling us to correct very nearly the spherical aberration by making the focus of each zone to coincide."—Brewster.

This description will enable the reader to understand the system which has been adopted by Fresnel and carried out by the French government, and by our own commissioners of lights.

In the fixed dioptic light of Fresnel, the flame is placed in the centre of the apparatus, and within a cylindrical reflector of glass, of a vertical refracting power, the breadth and height of a strip of light emitted by it being dependent upon the size of the flame and the height of the reflector itself; above and below is placed a series of reflecting prismatic rings or zones for collecting the upper and lower diverging rays, which, falling upon the inner side of the zone, are refracted, pass through the second side, where they suffer total reflection, and, passing out on the outer side of the zone, are again refracted. The effect of these zones is to lengthen the vertical strip of light, the size of which is dependent upon the breadth of the flame and the height of the apparatus.

In Fresnel's revolving light-house, a large flame is placed in the centre of a revolving frame which carries a number of lenses on a large scale and of various curvatures, for the avoidance of spherical aberration. With the view of collecting the diverging rays above the flame, an arrangement of lenses and silvered mirrors is placed immediately over it. By this compound arrangement, the simply revolving character of the apparatus is destroyed, as, in addition to the revolving lens, a vertical and fixed light is at all times seen, added to which a great loss of light must be sustained by the loss of metallic reflectors. In 1831, Messrs. Wilkins and Letourneau exhibited a catadioptric apparatus of great utility. It was thus described by the exhibitors:—

The first improvement has special reference to the light, and produces a considerable increase in its power, whilst the simplicity of the optical arrangements is also regarded. It consists, firstly, in completely dispensing with the movable central cylindrical lenses; secondly, it replaces these by a single revolving cylinder composed of four annular lenses and four lenses of a fixed light introduced between them; but the number of such varying according to the succession of flashes to be produced in the period of revolution.

The second improvement, of which already some applications that have been made serve to show the importance, consists in a new method of arranging the revolving parts, experience having shown that the arrangements at present in use are very faulty. A short time is sufficient for the action of the friction rollers, revolving on two parallel planes, to produce by a succession of cuttings a sufficiently deep groove to destroy the regularity of the rotary movement. To obviate this great inconvenience, the friction rollers are so placed and fitted, on an iron axis with regulating screws and traversing between two levelled surfaces, that when an indentation is made in one place they can be adjusted to another part of the plates which is not so worn.

The third improvement produces the result of an increase of the power of the flashes in revolving light-house apparatus to double what has been obtained hitherto. By means of lenses of vertical prisms placed in the prolongation of the central annular lenses, the diverging rays emerging from the catadioptric zone are brought into a straight line, and a coincidence of the three lenses is obtained.

The whole of the prisms, lenses, and zones are mounted with strength and simplicity, accurately fixed and polished to the correct curves according to their respective positions, so as to properly develop this beautiful system of Fresnel. The glass of which they are composed should be of the clearest crystal color, and free from that green hue which so materially reduces the power of the light, and is considered objectionable for
apparatus of this kind. The lamp by which the apparatus is to be lighted consists of a concentric burner with four circular wicks attached to a lamp of simple construction, the oil being forced up to the burner by atmospheric pressure only, so that there are no delicate pumps or machinery to become deranged.

Stephenson's revolving light-house.—This apparatus consists of two parts. The principal part is a right octagonal hollow prism composed of eight large lenses, which throw out a powerful beam of light whenever the axis of a single lens comes in the line between the observer and the focus. This occurs once in a minute, as the frame which bears the lens revolves in eight minutes on the rollers placed beneath. The subsidiary parts consist of eight pyramidal lenses inclined at an angle of 50° to the horizon, and forming together a hollow truncated cone, which rests upon the flame like a cap. Above these smaller lenses (which can only be seen by looking from below) are placed eight plane mirrors, whose surfaces are inclined to the horizon at 50° in the direction opposite to that of the pyramidal lenses, finally causing all the light made parallel by the refraction of these lenses to leave the mirror in a horizontal direction. The only object of this part is to turn to useful account, by prolonging the duration of the flash, that part of the light which would otherwise escape into the atmosphere above the main lenses. This is effected by giving to the upper lenses a slight horizontal divergence from the vertical plane of the principal lenses. Below are five tiers of totally reflecting prisms, which intercept the light that passes below the great lenses, and by means of two reflections and an intermediate refraction project them in the shape of a flat ring to the horizon.

In the Stephenson's fixed dioptric apparatus of the first order (same as that at the Isle of May, with various improvements,) the principal part consists of a cylindrical belt of glass which surrounds the flame in the centre, and by its action refracts the light in a vertical direction upwards and downwards, so as to be parallel with the focal plane of the system. In this way it throws out a flat ring of light equally intense in every direction. To near objects, this action presents a narrow vertical band of light, depending on the extent of the horizontal angle embraced by the eye. This arrangement therefore fulfills all the conditions of a fixed light, and surpasses in effect any arrangement of parabolic reflectors. In order to save the light which would be lost in passing above and below the cylindrical belt, curved mirrors with their common focus in the lamp were formerly used; but by the present engineer, the adaptation of catadioptric zones to this part of the apparatus was, after much labor, successfully carried out. These zones are triangular, and act by total reflection, the inner face reflecting, the second totally reflecting, and the third, or outer face, a second time reflecting, so as to cause the light to emerge horizontally. The apparatus has received many smaller changes by the introduction of a new mode of grouping the various parts of the framework, by which the passage of the light is less obscured in every azimuth.

Mechanical lamps of four wicks are used in these light-houses; in these the oil is kept continually overflowing by means of pumps which raise it from the cistern below; thus the rapid carbonization of the wicks, which would be caused by the great heat, is avoided. The flames of the lamp reach their best effect in three hours after lighting, i. e., after the whole of the oil in the cistern, by passing and repassing over the wicks repeatedly, has reached its maximum temperature. After this the lamp often burns 14 hours without sensible diminution of the light, and then rapidly falls. The height varies from 16 to 20 times that of the Argand flame of an inch in diameter; and the quantity of oil consumed by it is greater nearly in the same proportion.

In Stevenson's ordinary paraboloid reflector, rendered holophotal (where the entire light is parallelized) by a portion of a catadioptric annular lens, the back part of the parabolic conoid is cut off, and a portion of a spherical mirror substituted, so as to send the rays again through the flame; while his holophotal catadioptric annular lens apparatus is a combination of a hemispherical mirror and a lens having totally-reflecting zones; the peculiarity of this arrangement is, that the catadioptric zones, instead of transmitting the light in parallel horizontal plates, as in Fresnel's apparatus, produces, as it were, an extension of the bent or quinquaversal action of the central lens by assembling the light around its axis in the form of concentric hollow cylinders.

Mr. Chance, of Birmingham, constructed a light-house which may be regarded as Fresnel's revolving light rendered holophotal. This arrangement was divided into three compartments, the upper and lower of which were composed respectively of thirteen and six catadioptric zones which produce the vertical strip of light extending the whole length of the apparatus, and is similar to Fresnel's dioptric light. The central or catadioptric compartment consisted of eight lenses of three feet focal length, each of which was the centre of a series of eleven concentric prismatic rings, designed to produce the same refractive effect as a solid lens of equal size. These compound lenses were mounted upon a revolving frame and transmitted horizontal flashes of light as they successively rotated. The mechanism was so constructed to the frame by a clock movement, so that it performs one revolution in four minutes; consequently, as there are eight lenses, a flash of light is transmitted every thirty seconds to the horizon.
LINEN. 719

LIGNITE. In Prussia, Austria, and many other parts of the continent, lignite forms a very important product, being largely employed for domestic and for manufacturing purposes. In this country, with the single exception of the Bovey Heathfield formation, which is used in the adjoining pottery, lignite is not employed.

LIME. Quicklime, an Etchel of Calcination. This useful substance is prepared by exposing the native carbonate of lime to heat, by which the carbonic acid is expelled.

This operation is performed in a manner more or less perfect, by burning calcareous stones in kilns or furnaces.

Anhydrous lime, or, as it is commonly called, "quicklime," is an amorphous solid, varying much in coherency, according to the kind of rock from which it is obtained; its specific gravity varies from 2% to 3. Lime is one of the most infusible bodies which we possess: it resists the highest heats of our furnaces.

When exposed to air, quicklime rapidly absorbs water and crumbles into a powder, commonly known as slaked lime, which is a hydrate of lime.

Hydrate of lime, when exposed to the air, absorbs carbonic acid, and after long exposure it is converted into a mixture of carbonate of lime and hydrate of lime in single equations, say, 1 lime = 7 lime is slightly soluble in water, 729 to 733 parts of that fluid dissolving only 1 part of the lime at ordinary temperatures.

Hydrate of lime is applied to numerous purposes in the arts and manufactures. It is chiefly employed in the preparation of mortar for building purposes. See Mortar.

The pure limes, prepared from the carbonates of lime, form an imperfect mortar suitable for dry situations. In damp buildings or in wet situations they never set, (as the process of hardening is technically termed,) but always remain in a pulpy state. General Pasley says:—"The unfitness of pure lime for the purposes of hydraulic architecture has been proved by several striking circumstances that have come under my personal observation, of which I shall only mention a few. First, a great portion of the boundary wall of Rochester Castle having been completely undermined, nearly through its whole thickness, which was considerable, whilst the upper part of the same wall was left standing, I had always ascribed this remarkable breach to violence, considering it as having been the act of persons intending to destroy the wall for the sake of the stone; but on examining it more accurately after I had begun to study the subject of limes and cements, I observed that the whole of the breached part was washed by the Medway at high water, and that all the mortar of a small portion of the back part of the foot of the wall still left standing was quite soft, but that towards the ordinary high water level it became a little harder, and above that level it was perfectly sound. I observed the same process at the outer wall of Cockham Wood Fort, on the left bank of the Medway below Chatham, of which the upper part was standing, whilst the lower part of it had been gradually ruined by the action of the river at high water destroying the mortar."

Observations on limes, calcareous cements, &c.—The peculiar conditions necessary to insure a good and useful mortar for building purposes, and the peculiarities of the hydraulic mortars or cements, will be treated of under Mortar, which see.

LINEN. The manufacture of linens is carried on extensively in the north of Ireland, and on the continent in Bohemia, Moravia, Silesia, and Galicia. Of the entire production, independent of the Irish linen, about five-twelfths are brought into the market, and of this quantity the bulk must be of domestic manufacture, since few great linen manufactories exist in Austria. Within Austrian dominions, among the linen fabrics, tablecloths and napkins, socks, umbrellas, dimity, twills, and drills are important articles. In the next rank we must place the manufacture of thread, especially in Bohemia, Moravia, and Lombardy. The tape manufacture is of less consequence; and as to the business of dyeing and printing, that has been almost entirely absorbed by the cotton manufacture, and is now in requisition for thread and handkerchiefs only.

As the loss resulting from the processes of weaving, bleaching, &c., is estimated at about 10 per cent., the net aggregate of these manufactures of linen, thread, &c., may be assumed at, say, 1,027,000 cwt., of which quantity about 450,000 cwt. come into the market, the rest being absorbed by domestic consumption. Since, upon an average of the five years from 1843 to 1847, there appear to have been imported from abroad only 242 cwt., whereas the average of exports for the same period shows 42,609 cwt., it follows that there remained for home consumption about 1,000,000 cwt. Thus, on a population of 8,600,000 of persons, about 25 lbs. would fall to the share of each; but this estimate falls much below the truth, when we consider that the national costume in Hungary and Galicia requires more than double the quantity we have allowed for. In fact the crop of flax is estimated to be 10 per cent. higher than is given in the official reports; but the consumption of even 3 lbs. per head, which would thus result, is yet smaller than in reality it must be. In the imperial army of Austria the quantity used up annually by each man averages more than 7 lbs.

In the above statistics of the manufacture of linen goods no allowance has been made for the extensive production of rope work and the like.
LINSEED OIL. Linseed oil was at one time much used in the preparation of a liniment, which, as it is one of the very best possible applications to a burnt surface, cannot be too generally known. If equal parts of lime-water and linseed oil are agitated together, they form a thick liniment, which may be applied to the burnt with a brush or feather. It relieves at once from pain, and forming a pellicle, protects the abraded parts from the air. The Linum usitatissimum of the Pharmacopoeia is equal parts of lime-water and olive oil; this is a more elegant but a less effective preparation. See Oils.

LIQUORICE. (Glycyrrhiza Oficiinalis; from glykus, sweet, and rhiza, a root.) The root only is employed; these roots are thick, long, and running deep in the ground.

Besides the use of liquorice roots in medicine, they are also employed in brewing, and are partly extensively grow for these purposes in some parts of England. Liquorice requires a rich, deep, dry, sandy soil, which, previous to forming a new plantation, should be trenched to the depth of about three feet, and a liberal allowance of manure regularly mixed with the earth in trenching. The plunis, which are procured by slipping them from those in old plantations are, either in February or March, divided in rows three feet apart, and from eighteen inches to two feet in the row. They require three summers’ growth before being fit for use, when the roots are obtained by retrenching the whole, and they are then stored in sand for their preservation until required.—Peter Lawson.

LITHOGRAPHY. Engraving on stone, for maps, geometrical drawings of every kind, patent inventions, machinery, &c., is performed with a diamond point as clearly and distinctly as if executed on copper or steel plates; to print these engraved stones, the ink should be laid on with a dabber, not a roller. Another method is by preparing the surface of the stone with a thin covering, or etching ground, of gum and black, upon which the design is traced or engraved with an etching point; it then appears in white lines upon a black surface. In this state the stone is taken to the printer, who applies ink to the engraved part, and washing off the gum, the drawing appears in black lines upon the white surface of the stone, and after being submitted to the process of fixing, described below, is ready for printing.

Litholint, a process of drawing upon stone was adopted, first, by Mr. J. D. Harding, a few years back, and since by one or two other artists; several works were at the time executed by this method, which consists in painting the subject with a camel hair pencil, dipped in a preparation of liquid lithographic chalk, using the latter as if it were an ordinary color, or Indian ink, sepia, &c. The results of this process were, however, so uncertain in printing, that it has been almost, if not entirely, abandoned.

The process of printing a subject executed in lithography is as follows:—The drawing is first executed by the artist on the stone in as perfect and finished a manner as if done on paper or card-board: the stone is then washed over with nitric acid, diluted with gum, which neutralizes the alkali, or soap, contained in the chalk, fixes the drawing, and cleans the stone at the same time; this is technically called etching. The acid is then washed off with cold water, and any particles of the crayon or other substances which may have adhered to the surface, are removed by the application of a sponge dipped in spirits of turpentine: the stone is now ready for printing; it is slightly wetted, charged with printing-ink by means of a roller, the sheet of paper, which is to receive the impression, is laid on it in a damp state, and the whole is passed through the press.

Chromolithography, or printing in colors from stones, (χρωμα, color,) is a comparatively recent introduction, but has been brought to such perfection, that works of art of the highest pictorial excellence are sometimes so closely imitated as to deceive very competent judges. A portrait of Shakespeare, for example, executed in chromolithography by Mr. Vincent Brooks, of London, from an old oil painting, is so marvellous a copy of the original as almost to defy detection. Chromolithography, as a beautiful medium of illustration, is now in very general use. The process may be thus described: A drawing of the subject, in outline, on transfer tracing-paper, is made in the ordinary way: when transferred to a stone, this drawing is called the key-stone, and it serves as a guide to all the others, for it must be transferred to as many different stones as there are colors in the subject; as many as thirty stones have been used in the production of one colored print. The first stone required, generally for flat, local tints, is covered with lithographic ink where the parts should be of solid color; the different gradations are produced by rubbing the stone with rubbing-stuff, or tint-ink, made of soap, shell lac, &c., &c., and with a painted lithographic chalk where necessary; the stone is then washed over with nitrous acid, and goes through the entire process described above. A roller charged with lithographic printing-ink is then passed over it to ascertain if the drawing comes as desired; and the ink is immediately afterwards washed off with turpentine; if satisfactory, this stone is ready for printing, and is worked off in the requisite color; the next stone undergoes the same process for another color, and so with the rest till the work is complete; it will of course, be understood, that before any simple impression is finished, it will have to pass through as many separate
LOCKS.

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printings as there are drawings on stones. The colors used in printing are ground up with burnt linseed oil, termed varnish. — J. D.

LITMUS. Dr. Pereira, writes:—“Litmus is imported from Holland, in the form of small, rectangular, light, and friable cakes of an indigo blue color. Examined by the microscope, we find sporules and portions of the epidermis and mesothallus of some species of lichen, moss, leaves, sand, &c. The odor of the cakes is that of indigo and violets. The violet odor is acquired while the mixture is undergoing fermentation, and is common to all the tinctorial lichens. It has led some writers into the error of supposing that the litmus makers use Florentine orris in the manufacture of litmus. The indigo color depends on the presence of indigo in the litmus cakes.”

LITMUS PAPER. Paper colored with an infusion of litmus, used as a test for the presence of acids.

Faraday, in his Chemical Manipulation, recommends an infusion of one ounce of litmus, and half a pint of hot water. Bibulous paper is saturated with this. Professor Graham prefers good letter paper to the unsized paper. In order to obtain very delicate test-paper, the alkali in the litmus must be almost neutralized by a minute portion of acid.

LOCKS. Although locks are distinctly a manufacture, yet they were not embraced in former editions of this work, the chief cause of this being the desire on the part of Dr. Ure to limit the articles of the dictionary to such manufactures as were not comprehended within his meaning of the term handicraft.

The lock manufacture is essentially one of handicraft, and seeing that these volumes could not possibly enter into any detailed description of this and numerous other trades, as watchmaking and the like, it has been determined that a brief notice of the several kinds of locks alone shall find a place in its pages.

The lock manufacture of this country is confined almost exclusively to Wolverhampton and the neighboring village of Willehall. There are very few large manufactories, almost all kinds of locks being made by small masters, employing from half a dozen to a dozen men.

In nearly every kind of lock, a bolt shoots out from the box or lock, usually of an oblong shape, and catches in some kind of staple or box fixed to receive it. In some a staple enters the lock, and the bolt passes through the staple within the lock. The lock of a room door is of the first character. The lock of a writing desk, or ordinary box, is of the second kind. The key is merely a bent piece of iron which, on entering the lock, can move freely and push forward the bolt. To the bolts of superior locks, springs are attached, and the force required to turn the key in a lock is the force necessary to overcome the resistance of the springs. The following two figures, (413, 414), represent the character

of a lock with wards or wheels which are introduced to give safety. Fig. 413 is an ordinary back-spring lock, representing the bolt half shot; $a'$ and $a''$ are notches on the under side of the bolt connected by a curved portion; $b$ is the back-spring, which is of course compressed as the curved portion of the bolt passes through the aperture prepared for it in the rim of the lock; when the bolt is withdrawn, the notch $a'$ rests in the rim; when the bolt is shot, the notch $a''$ rests in the same manner. The action of the key and wards is shown in fig. 414. The curved pieces of metal are the wards; and there are two clefts in the bit of the key to enable it to move without interruption.

The tumbler lock is shown in its most simple form in fig. 415. Here the bolt has two slots $a$ in the upper part; and behind the bolt is a kind of latch $b$ which carries a projecting piece of metal $c$; this is the tumbler, which moves freely on a pivot at the other end. When the bolt is fully shot, the projecting piece of metal falls into one notch; and when withdrawn, it falls into the other. It will be evident here, that the action of the key is to raise the tumbler, so that the bolt has free motion; this action will be intelligible by
tracing the action of the key on the dotted lines. These tumbler locks are greatly varied in character; but in principle they are as above described. Numerous well-known locks have been patented, the most remarkable being Chubb's lock, which has been fully described by the inventors in a paper read before the Institution of Civil Engineers; and also in an excellent treatise on locks, to be found in Mr. Weale's series of useful manuals. This lock is essentially a tumbler lock, it being fitted up with no less than six tumblers; and the key has to raise by a series of steps these, before the bolt is free to move. It will be obvious, that unless the key is exactly fitted to move these, there is no chance of moving the bolt. In his paper already alluded to, Mr. Chubb says:

"The number of changes which may be effected on the keys of a three-inch drawer lock is \(1 \times 2 \times 3 \times 4 \times 5 \times 6 = 720\), the number of different combinations which may be made on the six steps of unequal lengths, without altering the length of either step. The height of the shortest step is however capable of being reduced 20 times; and each time of being reduced, the 720 combinations may be repeated; therefore 720 \( \times 20 = 14,400\) changes.\(^8\) By effecting changes of this character, therefore, almost any number of combinations can be produced. The Bramah lock has been long celebrated, and most deservedly so. Notwithstanding the fact that this lock was picked by Mr. Hobbs after having the lock in his possession for sixteen days, it appears to us that it most fully justifies the claims put forth in his "Dissertation on the Construction of Locks."\(^9\) "Being confident," he says, "that I have contrived a security which no instrument but its proper key can reach, and which may be so applied as not only to defray the art and ingenuity of the most skilful workman, but to render the utmost force ineffectual, and thereby to secure what is most valued as well from dishonest servants as from the midnight ruffian, I think myself at liberty to declare (what nothing but the discovery of an infallible remedy would justify my declaring) that all dependence on the inviolable security of locks, even of those which are constructed on the best principle of any in general use, is fallacious." He then proceeds to demonstrate the imperfections of ordinary locks and to describe his own:

"The body of a Bramah lock may be considered as formed of two concentric brass barrels, the outer one fixed, and the inner rotating within it. The inner barrel has a projecting stud, which, while the barrel is rotating, comes in contact with the bolt in such a way as to shoot or lock it; and thus the stud serves the same purpose as the bit of an ordinary key, rendering the construction of a bit to the Bramah key unnecessary. If the barrel can be made to rotate to the right or left, the bolt can be locked or unlocked, and the problem is, therefore, how to insure the rotation of the barrel. The key, which has a pipe or hollow shaft, is inserted in the keyhole upon the pin, and is then turned round; but there must be a nice adjustment of the mechanism of the barrel before this turning round of the key and the barrel can be insured. The barrel has an external groove at right angles to the axis, penetrating to a certain depth; and it has also several internal longitudinal grooves from end to end. In these internal grooves thin pieces of steel are able to slide, in a direction parallel with the axis of the barrel. A thin plate of steel, called the locking plate, is screwed in two portions to the outer barrel, concentric with the inner barrel; and at the same time occupying the external circular groove of the inner barrel; this plate has notches, fitted in number and size to receive the edges of the slides which work in the internal longitudinal grooves of the barrel. If this were all, the barrel could not revolve, because the slides are catching in the grooves of the locking plate; but each slide has also a groove, corresponding in depth to the extent of this entanglement; and if this groove be brought to the plane of the locking plate, the barrel can be turned, so far as respects the individual slide. All the slides must, however, be so adjusted, that their grooves shall come to the same plane; but, as the notch is cut at different points in the lengths of the several slides, the slides have to be pushed in to different distances in the barrel in order that this juxtaposition of notches may be insured. This is effected by the key, which has notches or clefts at the end of the pipe equal in number to the slides, and made to fit the ends of the slides when the key is inserted; the key presses each slide, and pushes it so far as the depth of its cleft will permit; and all these depths are such that all the slides are pushed to the exact position where their notches all lie in the same plane; this is the plane of the locking plate, and the barrel can be then turned."\(^9\) (Tombilhon on the Construction of Locks.) In this work the details on construction are given with great clearness.

The American bank locks, especially that of Messrs. Day and Newall, have excited much attention. Their English patent describes it thus:

"The object of the present improvements is the constructing of locks in such manner
LOCKS.

that the interior arrangements, or the combination of the internal movable parts, may be changed at pleasure according to the form given to, or change made in, the key, without the necessity of arranging the movable parts of the lock by hand, or removing the lock or any part thereof from the door. In locks constructed on this plan, the key may be altered at pleasure; and the act of locking, or throwing out the bolt of the lock, produces the particular arrangements of the internal parts, which correspond to that of the key for the time being. While the same is locked, this form is retained until the lock is unlocked or the bolt withdrawn, upon which the internal movable parts return to their original position, with reference to each other; but these parts cannot be made to assume or be brought back to their original position, except by a key of the precise form and dimensions as the key by which they were made to assume such arrangement in the act of locking. The key is changeable at pleasure, and the lock receives a special form in the act of locking according to the key employed, and retains that form until, in the act of unlocking by the same key, it resumes its original or unlocked state. The lock is again changeable at pleasure, simply by altering the arrangement of the movable bits of the key: and the key may be changed to any one of the forms within the number of permutations of which the parts are susceptible."

—April 15, 1831.

Mr. Hobbs, who has been carrying out the manufacture of American locks in this country has introduced an inexpensive lock, which he calls a protector lock. The following description is borrowed from Mr. Charles Tomlinson's Treatise on the Construction of Locks:

"When the American locks became known in England, Mr. Hobbs undertook the superintendence of their manufacture, and their introduction into the commercial world. Such a lock as that just described must necessarily be a complex piece of mechanism; it is intended for use in the doors of receptacles containing property of great value, and the aim has been to combine all the methods at present known of picking locks, by a combination of mechanism necessarily elaborate. Such a lock must of necessity be costly; but in order to supply the demand for a small lock at moderate price, Mr. Hobbs has introduced what he calls a protector lock. This is a modification of the ordinary six-tumbler lock. It bears an affinity to the lock of Messrs. Day and Newall, inasmuch as it is an attempt to introduce the same principle of security against picking, while avoiding the complexity of the changeable lock. The distinction which Mr. Hobbs has made between secure and insecure locks will be understood from the following proposition, viz. 'that whenever the parts of a lock which come in contact with the key are so affected by any pressure applied to the bolt, or to that portion of the lock by which the bolt is withdrawn, as to indicate the points of resistance to the withdrawal of the bolt, such a lock can be picked.' Fig. 417 exhibits the internal mechanism of this new patent lock. It contains the usual contrivances of tumblers and springs, with a key cut into steps to suit the different heights to which the tumblers must be raised. The key is shown separately in fig. 418. But there is a small additional piece of mechanism, in which the tumbler stump shown at \( a \) in figs. 416 and 417 is attached; which piece is intended to work under or behind the bolt of the lock. In fig. 417 \( b \) is the bolt; \( t t \) is the front or foremost of the range of six tumblers, each of which has the usual slot and notches. In other tumbler-locks the stump or stud which moves along these slots is riveted to the bolt, in such manner that, if any pressure be applied in an attempt to withdraw the bolt, the stump becomes pressed against the edges of the tumblers, and bites or binds against them. How far its biting facilitates the picking of a lock will be shown further on; but it will suffice here to say, that the movable action given to the stump in the Hobbs lock transfers the pressure to another quarter. The stump \( s \) is riveted to a peculiarly-shaped piece of metal \( p \), (fig. 416,) the hole in the centre of which fits upon
LOCOMOTIVE ENGINES.

A centre or pin in a recess formed at the back of the bolt; the piece moves easily on its centre, but is prevented from so doing spontaneously by a small binding spring. The mode in which this small movable piece takes part in the action of the lock is as follows: when the proper key is applied in the usual way, the tumblers are all raised to the proper heights for allowing the stump to pass horizontally through the gating; but should there be an attempt made, either by a false key or by any other instrument, to withdraw the bolt before the tumblers are properly raised, the stump becomes an obstruction to its passage, the stump turns the piece to which it is attached on its centre, and moves the arm of the piece so that it shall come into contact with a stud riveted into the case of the lock; and in this position there is a firm resistance against the withdrawal of the bolt. The tumblers are at the same moment released from the pressure of the stump. There is a dog or lever which catches into the top of the bolt, and thereby serves as an additional security against its being forced back. At k is the stall-pin on which the pipe of the key works; and r is a metal piece on which the tumblers rest when the key is not operating upon them.

Another lock, patented by Mr. Hobbs in 1852, has for its object the absolute closing of the key-hole during the process of locking. The key does not work or turn on its own centre, but occupies a small cell or chamber in a revolving cylinder, which is turned by a fixed handle. The bit of the movable key is entirely separable from the shaft or stem, into which it is screwed, and may be detached by turning round a small milled headed thumb-screw. The key is placed in the key-hole in the usual way, but it cannot turn; its circular movement round the stem as an axis is prevented by the internal mechanism of the lock; it is left in the key-hole, and the stem is detached from it by unscrewing. By turning the handle the key-bit, which is left in the cylinder, comes in contact with the works of the lock, so as to shoot and withdraw the bolt. This revolution may take place whether the bit of the movable key occupy its little cell in the plate or not; only with this difference—that if the bit be not in the lock, the plate revolves without acting upon any of the tumblers; but if the bit be in its place, it raises the tumblers in the proper way for shooting or withdrawing the bolt. It will be understood that there is only one key-hole, that through which the divisible key is inserted; the other handle or fixed key working through a hole in the cover of the lock only just large enough to receive it, and not being removable from the lock. As soon as the plate turns round so far as to enable the key-bit to act upon the tumblers, the key-holes become entirely closed by the plate itself, so that the actual locking is effected at the very time when all access to the interior through the key-hole is cut off. When the bolt has been shot, the plate comes round to its original position, it uncovers the key-hole, and exhibits the key-bit occupying the little cell into which it had been dropped; the stem is then to be screwed into the bit, and the latter withdrawn. It is one consequence of this arrangement, that the key has to be screwed and unscrewed when used; but through this arrangement the key-hole becomes a sealed body to one who has not the right key. Nothing can be moved, provided the bit and stem of the key be both left in; but by leaving in the lock the former without the latter, the plate can rotate, the tumblers can be lifted, and the bolt can be shot.

LOCOMOTIVE ENGINES. The character of this work excludes any special notice of a subject so entirely belonging to a work on Mechanical Engineering, as that of locomotive engines. Nevertheless, since so much has lately been said and written on the question of employing coal on our railways instead of coke, we are induced to introduce the following arrangement, which secures combustion without smoke. It is known as Durney's plan. The annexed drawing, (fig. 419,) is a section of a locomotive engine, used on the Chalon's Railway. The coal is thrown into the side pipes a, which open below the platform on which the engine-man stands. These pipes conduct the coal by their own gravity to the lower level of the bars, where they are thrust in the direction of the arrows e, by a kind of comb, or rotating pin, which, in its rotation around the axle e, forces the coal to ascend the incline forward by the bars.

This then takes place, the coal in its rude state (i. e. as it comes from the pit) coming from below, finds itself immediately in contact with the fire, which induces an escape of the gases, and with the pure air which permits their combustion to take place in the only condition in which it is possible, i. e. in small jets, which facilitate the complete oxygenation of all the parts.

The gases once produced and burnt, the rest of the operation scarcely needs explanation. The coal is converted into coke, and finishes its passage while burning under this form: and as the remainder of the solids, cinders and slag, (or clinkers,) are not abandoned by the fire until after all that it contains of a combustible nature has disappeared, all the detritus (refuse) and dust, cinders, ashes, &c., are deposited on the surface (sommet) of the bars in the centre of the fire, where they would offer an obstruction similar to that found in ordinary fire-places, if the inventor had not taken care to make the bars oscillate from the centre by a small movement. Thus, when a drop of slag approaches the bars, it is displaced and
threw out (by the opening of the bars) in small particles. This accessory arrangement apparently possesses great advantages for a locomotive in saving the trouble of scraping and cleaning the bars.

So if, as in an ordinary fire, coke or anthracite, &c., be burnt, the combustion would be very complete. Air fresh from the ash-pan, in passing over the combustible, would be converted into carbonic acid, i.e., into a gas which is unfit for further combustion. But if in the place of coke or anthracite, &c., we use smoke-producing coal, i.e., composed of two elements, one solid, the other gaseous, this result follows: The combustible gases disengaging themselves (in this case above the combustible) in a state of ignition, the air which will become vitiated in traversing the first bed of the solid combustible, will be found unable to effect the combustion of the gases which escape above the fire, and smoke will make its appearance, i.e., the combustion will be incomplete and imperfect. This is what takes place with combustion of coal in ordinary fire-places.

There are also other causes which contribute to the imperfection of this result. These gases in disengaging themselves do not always acquire a temperature sufficiently high to produce flame, and the volume of combustible gas is almost too considerable to allow of its being sufficiently penetrated with oxygen. These are some of the radical vices which M. Duméry has removed in thus placing the gases at once in the condition best suited for their combustion. This process is admirable, since, without any preparation, it allows of coal being burnt with as much facility as coke, and saves the great expense of converting coal into coke.

LODE, (a mining term). A mineral lode, or a mineral vein, is the name given to a fissure in the crust of the earth which has been filled in with metalliciferous matter. The miner gives the same name lode to a fissure filled with quartz, carbonate of lime, &c., but then he says the lode is not "mineralized," confining the word mineral to metalliciferous matter.

The term vein has frequently led to the idea that expresses the condition of something analogous to the blood-vessels of the animal body, to which a lode has not in the remotest degree any resemblance. During some primary convulsions, the crust of the earth has been cracked, these fissures having, of course, some special relation to the direction of the force which produced them. These cracks have during ages of submersion been filled in, according to some law of polarity with mineral matter, the character of the lode having generally some special relation to its direction. See Mining, &c.

LUCIFER MATCHES. The importance of this manufacture has been shown by Mr. Tomlinson in a communication made by that gentleman to the Journal of the Society of Arts.

"It has been estimated," he says, "that the English and French manufacturers of phosphorus are now producing at the rate of 300,000 lbs. of common phosphorus per annum, nearly the whole of which is consumed in making lucifer matches. In compounding the emulsion for tipping the matches, the German manufacturers make three pounds of phosphorus suffice for five or six millions of matches. If we suppose only one half of the French and English annual product of phosphorus to be employed in making matches, this will give us 250,000,000,000 of matches as the annual product consequent on the consumption of one-half of the French and English phosphorus. We need not suppose this to be an exaggerated statement, when we consider the daily product of some of our match manufactories. I lately had occasion to describe the processes of a London factory, which produces 2,500,000 matches daily. For this purpose, 14-5-inch planks are cut up; each plank produces 30 blocks; each block, of the dimensions
of 11 inches long, 4½ inches wide, and 3 inches thick, produces 100 slices, each slice 31 splinters, each splinter 3 matches: thus we have—$14 \times 50 \times 100 \times 31 \times 2 = 2,604,000$ matches as the day's work of a single factory in London. At Messrs. Dixon's factory near Manchester, from 5,000,000 to 9,000,000 of matches are produced daily. —Tondioson.

A "Safety Lucifer Match," as it is called, has been manufactured in Sweden. A patent was obtained in that country by Messrs. Bryant and May, for this match. Its peculiarity consists in the division of the combustible ingredients of the lucifer between the match and the friction paper. In the ordinary lucifer, the phosphorus, sulphur, and chlorate of potash or nitre, are all together on the match, which ignites when rubbed against any rough substance. In the Swedish matches these materials are so divided that the phosphorus is placed on the sand-paper, whilst the sulphur and a minimum amount of chlorate of nitre of potash is placed on the match. In virtue of this arrangement it is only when the phosphorized sand-paper and the sulphurized match come in contact with each other that the ignition occurs. Neither match nor sand-paper, singly, takes fire by moderate friction against a rough surface.

The composition of lucifer matches varies greatly, as it regards the proportions of the materials employed. In principle they are, however, as we have described them above, every thing depending on the ignition of the phosphorus, and the perfection of a lucifer match is in tipping the match with a composition which will ignite quietly upon attrition against any rough surface, but which is not liable to ignition by such pressure as it may be subjected to under the ordinary condition of keeping in closed boxes.

The preparation of lucifer matches has been attended with much human suffering. Every person engaged in a factory of this kind is more or less exposed to the fumes of phosphorus, and this exposure produces a disease which has been thus described by Mr. Harrison, in the Quarterly Journal of Medical Science — "This disease," he says, "is of so insidious a nature that it is at first supposed to be common toothache, and a most serious disease of the jaws is produced before the patient is fully aware of his condition. The disease gradually creeps on, until the sufferer becomes a miserable and loathsome object, suffering during the best period of his life in the wards of a public hospital. Many patients have died of the disease; many, unable to open their jaws, have lingered with carious and necrosed bones; others have suffered dreadful mutilations from surgical operations, considering themselves happy to escape with the loss of the greater portion of the lower jaw."

By the introduction of an amorphous phosphorus discovered by M. Schröder, which is in nearly all respects unlike the ordinary phosphorus, but which answers exceedingly well for the manufacture of lucifer matches, this disease is prevented, the manufactory is rendered more healthy, and the boxes of matches themselves less dangerous. See Phosphores.

In 1857 our imports and exports were—

<table>
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<th>Imports</th>
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<th>-</th>
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<td>-</td>
<td>5,604,460</td>
<td>-</td>
<td>47</td>
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</table>

LUMACHELLE, or Fire Marble. This is a dark brown shelly marble, having brilliant fire or chatonvert reflections from within.—See Marble.

LUNAR CAUSTIC. A name for nitrate of silver, when fused and run into cylindrical moulds.

LUSTRING, sometimes spelled and pronounced Lutestring; a peculiar shining silk.

LUTEOLINE, is the coloring principle of the weld, (Reseda luteola,) a slender plant growing to the height of about three feet, and cultivated for the use of dyers. When ripe it is cut and dried.

Chevreul was the first to separate the luteoline; it is extracted from the weld by boiling water, and when this solution is concentrated and allowed to cool, the luteoline separates; it is then collected, dried, and submitted to sublimation, when it is condensed in yellow needles.

It is valued for its durability, and is used as a yellow dye, on cottons principally, and also on silks, but is little used at present. It was formerly used by paper-hanging manufacturers, to form a yellow pigment, but has been entirely superseded for that purpose, by quercetin bark and Persian berries. It unites with acids and alkalis, the former making the color paler, and the latter heightening the color. The compound which it forms with potash is of a golden color, becoming greenish when exposed to the air, by absorption of oxygen, and at length becomes red.

It forms yellow compounds with alum, protochloride of tin, and acetate of lead; with the salts of iron it produces a blackish gray precipitate, and with sulphate of copper a greenish brown precipitate.

It is readily soluble in alcohol and ether, but sparingly so in water.—H. K. B.
MADDER. (Garance, Fr.; Krapp, Färberöthe, Germ.) A substance very extensively used in dyeing, is the root of the Rubia tinctorum, Linn. It is employed for the production of a variety of colors, such as red, pink, purple, black, and chocolate.

The Levant madder, usually called Turkey roots, is considered to be the finest quality imported into this country. It comes to us from Souchna, and consists of the root of the plant broken into small pieces and packed in bales. It is ground as it is, without any attempt being made to separate the different portions of the root; and has then the appearance of a coarse dark reddish-brown powder. It is employed chiefly for the purpose of dyeing the finer purples on calico. Next to this comes the madder of Avignon, of which two varieties are distinguished in commerce, viz.: Paluds and roots. The first, which is the finest, owes its name to the district in which it is grown, consisting of a small tract of reclaimed marsh-land in the neighborhood of Avignon. Avignon madder is considered to be the best adapted for dyeing pink. It has the appearance, as imported into this country, of a fine, pale yellowish-brown or reddish-brown powder. The paler color, as compared with that of ground roots, is owing to the partial separation of the external or cellular portion of the root during the process of grinding, as practised in France. The madders of Alsace, Holland, and Naples are richer in coloring matter than the two preceding kinds, but they yield less permanent dyes, and are therefore only employed for colors which require little treatment with soap, and other purifying agents after dyeing. Of late years, indeed, the employment of Garancine, a preparation of madder, in the place of these lower descriptions, has become very general.

All kinds of madder have a peculiar, indescribable smell, and a taste between bitter and sweet. Their color varies extremely, being sometimes yellow, sometimes orange, red, reddish-brown, or brown. They are all more or less hygroscopic, so that even when closely packed in casks in a state of powder, they slowly attract moisture, increase in weight, and at length lose their pulverulent condition, and form a firm, coherent mass. This change takes place to a greater extent with Alsace and Dutch madders, than with those of Avignon. Madder which has undergone this change is called by the French Garancine. It is probable that some process of fermentation goes on at the same time, for madder that is kept in casks in a dry place, and as much out of contact with the air as possible, is found constantly to improve in quality for a certain length of time, after which it again deteriorates. Some kinds of madder, especially those of Alsace and Holland, when mixed with water and left to stand a short time, give a thick conglom or jelly, which does not take place to the same degree with Avignon madder. The madder of Avignon contains so much carbonate of lime as to effervescence with acids. The herbaceous parts of the plant, when given as fodder to cattle, are found to communicate a red color to their bones—a circumstance which was first observed about a hundred years ago, and has been employed by physiologists to determine the manner and rate of growth of bone.

There exists no certain means of accurately ascertaining the intrinsic value of any sample of madder, except that of dyeing a certain quantity of mordanted calico with a weighed quantity of the sample, and comparing the depth and solidity of the colors with those produced by the same weight of another sample of known quality, and even this method may lead to uncertain results, if practised on too small a scale. The Paluds, which is the most esteemed of the Avignon madders, has a dark red hue, whereas the other kinds have naturally a yellow, reddish-yellow or brownish-yellow color. Nevertheless, means have been devised of communicating to the latter the desired reddish tinge, which, therefore, no longer serves as a test. A method formerly employed to ascertain the comparative value of a number of samples of madder consisted in placing a small quantity of each sample on a slate, pressing the heaps flat with some hard body, and then taking them to a collar or other damp place. After 10 or 12 hours they were examined, and that which had acquired the deepest color, and increased the most in volume, was considered the best. This method led, however, to so many frauds on the part of the dealer, for the purpose of producing the desired effect, that it is no longer resorted to. Madder is sometimes adulterated with sand, clay, brick-dust, ochre, saw-dust, bran, oak-bark, logwood and other dye-woods, sumace and quercitron bark. Some of these additions are difficult to detect. Such as contain tannin may be discovered by the usual tests, since madder contains naturally no tannin. If the material used for adulteration be of mineral nature, its presence may be discovered by incinerating a weighed quantity of the sample. If the quantity of ash which is left exceeds 10 per cent. of the material employed, adulteration may be suspected. The ash obtained by incinerating pure madder consists of the carbonates, sulphates, and phosphates of potash and soda, chloride of potassium, carbonate and phosphate of lime, phosphate of magnesia, oxide of iron and silica. If a considerable amount of other material constituent is found, it is certainly due to adulteration.
MADDER.

There is probably no subject connected with the art of dyeing which has given rise to so much discussion as the composition of madder, and the chemical nature of the coloring matters to which it owes its valuable properties. The subject has engaged the attention of a number of chemists, whose labors, extending over a period of about fifty years, have thrown considerable light on it. Nevertheless, the conclusions at which they have severally arrived do not perfectly agree with one another, nor with the views entertained by the most intelligent of those practically engaged in madder dyeing. The older investigators supposed that madder contained two coloring matters, one of which was tawny, and the other red. Robiquet was the first chemist who asserted that it contained two distinct red coloring matters, both of which contributed to the production of the dyes for which madder is employed; and his views, though they were at the time of their promulgation strongly objected to by some of the most eminent French dyers and calico printers, still offer probably the best means of explaining some of the phenomena occurring during the process of madder dyeing. The two red coloring matters discovered by Robiquet were named by him Alizarine and Purpurine, and these names they still retain. Several crystallized yellow coloring matters have been discovered by other chemists; but the only one which exists ready-formed in the madder of commerce is the Rubiacine of Schenck, and this substance may also be taken as the type of the whole class, the members of which possess very similar properties. Among the other organic substances obtained by different chemists from madder, two resinous coloring matters, sugar, a bitter principle, a peculiar extractive matter, pectin, a fermentative nitrogeneous substance, and mali, citric, and oxalate acids, may be mentioned.

When madder is extracted with boiling water, a dark brown muddy liquid, having a taste between bitter and sweet, is obtained. On adding a small quantity of an acid to this liquid, a dark brown precipitate is produced, while the supernatant liquid becomes clear, and now appears of a bright yellow color. The precipitate consists of alizarine, purpurine, rubiacine, the two resinous coloring matters, pectic acid, oxidized extractive matter, and a peculiar resinous substance. The liquid filtered from this precipitate is known as the liquid homogenate. The precipitate, the liquid homogenate, and the extractive matter of madder, as well as sugar and salts of potash, lime, and magnesia. No starch, gum, or tannin, can be detected in the watery extract. After the madder has been completely exhausted with boiling water, it appears of a dull red color. It still contains a quantity of coloring matter, which cannot, however, be extracted with hot water, or even alkalies, since it exists in a state of combination with lime and other bases; and his views, though they were at the time of their promulgation strongly objected to by some of the most eminent French dyers and calico printers, still offer probably the best means of explaining some of the phenomena occurring during the process of madder dyeing. The two red coloring matters discovered by Robiquet were named by him Alizarine and Purpurine, and these names they still retain. Several crystallized yellow coloring matters have been discovered by other chemists; but the only one which exists ready-formed in the madder of commerce is the Rubiacine of Schenck, and this substance may also be taken as the type of the whole class, the members of which possess very similar properties. Among the other organic substances obtained by different chemists from madder, two resinous coloring matters, sugar, a bitter principle, a peculiar extractive matter, pectin, a fermentative nitrogeneous substance, and mali, citric, and oxalate acids, may be mentioned.

A short description of some of the substances just mentioned will not be out of place here, as it may assist in rendering the process of dyeing with madder more intelligible. The most important of these substances is alizarine, since it forms the basis of all the finer and more permanent dyes produced by madder. The matière colorante rouge of Persoz and the madder-red of Runge also consist essentially of alizarine, mixed with some impurities. Robiquet first obtained it in the form of a crystalline sublimate, by extracting madder with cold water, allowing the liquid to gelatinize, treating the jelly with alcohol, evaporating the alcoholic liquid to dryness and heating the residue; and since the application of heat seemed to be an essential part of this process, it was for a long time doubted whether alizarine was contained as such in madder, and was not a product of decomposition of some other body. It was proved, however, by the experiments of Schenck, that it does in reality pre-exist in the ordinary madder of commerce, though not in the fresh root when just taken out of the ground. It has the following properties:—It crystallizes in long, transparent, lustrous, yellowish-red needles. These needles, when heated to 212° F., lose their water of crystallization and become opaque. At about 420° F. alizarine begins to sublime, and if carefully heated may be almost entirely volatilized, only a little charcoal being left behind. The sublimate obtained by collecting the vapors consists of long, brilliant, transparent, orange-colored crystals, which are pure anhydrous alizarine. If madder, or any preparation or extract of madder, be heated to the same temperature, a sublimate of alizarine is also obtained, but the crystals are then generally contaminated with drops of empyreumatic oil, produced by the decomposition of other constituents of the root. This oily matter may, according to Robiquet, be removed by washing the crystals with a little cold alcohol. Alizarine is almost insoluble in cold water. It is only slightly soluble in boiling water, and is deposited, on the solution cooling, in yellow crystalline floccs. When the water contains large quantities of acid or salts in solution, it dissolves very little alizarine, even in boiling. The color of the solution is yellowish when it is quite free from
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Alizarine dissolves much more readily in alcohol and ether than in water; the solutions have a deep yellow color. Alizarine is decomposed by chlorine, and converted into a colorless product. It is also decomposed by boiling nitric acid, the product being a colorless, crystallized acid, phthalic acid, the same that is formed by the action of nitric acid on naphthaline. Alizarine dissolves in concentrated sulphuric acid, yielding a yellow solution, which may be heated to the boiling point without changing color and without any decomposition of the alizarine, which is precipitated unchanged on the addition of water. Alizarine dissolves in caustic alkalies with a splendid purple or violet color, which remains unchanged on exposure of the solutions to the air. The ammonical solution, however, loses its ammonia entirely on being left to stand in an open vessel, and deposits its alizarine in the form of shining prismatic crystals, or of a crystalline crust. The alkaline solutions give with solutions of lime and baryta salts, precipitates of a beautiful purple color, with alumina salts a red, with iron salts a purple precipitate, and with most of the salts of metallic oxides precipitates of various shades of purple. The affinity of alizarine for alumina is so great, that if the compound of the two bodies be treated with boiling caustic potash lye, it merely changes its color from red to purple, without being decomposed. Alizarine is not more soluble in boiling alum liquor than in boiling water. The chemical formula of anhydrous alizarine is probably C₁₈H₁₄O₄, and 100 parts contain therefore by calculation 69·12 of carbon, 4·13 of hydrogen, and 26·45 of oxygen.

If alizarine in a finely divided, or, what is still better, in a freshly precipitated state, be suspended in distilled water, and a piece of calico printed with alumina and iron mordants of different strengths be plunged into it, the latter, on gradually heating the bath, become dyed. The color, communicated to the cloth, is only slightly, bubble in boiling water, and as the mordants can only combine with that portion actually in solution, a constant ebullition of the liquid must be kept up, in order to cause fresh portions of coloring matter to dissolve in the place of that portion taken up by the mordants. A very small proportional quantity of alizarine is required in order to dye very dark colors, but it is absolutely necessary that the bath should contain no trace of either acid or base, since the former would combine with the mordants, and the latter with the alizarine. When the process is complete, the alumina mordant will be found to have acquired various shades of red, while the iron mordant will appear either black or of different shades of purple, according to the strength of the mordant employed. These colors are as brilliant and as permanent as those obtained from madder by means of a long and complicated process. Nevertheless, the red is generally found to have more of a purplish hue, and the black to be less intense than when madder or its preparations are employed. On the other hand, if one of the finer madder colors which are produced on calico, as pink or lilac, be examined, the colors are found to contain, in combination with the mordants, almost pure alizarine. Hence it may be inferred, that alizarine alone is required for the production of these colors, and that the simple combination of this coloring matter with the mordants is the principal end which is to be attained by the dyer in producing them.

Purpurine, the other red coloring matter of madder, with which the madder colorante rose of Gaultier de Claubry and Persoz, and the madder-purple of Runge, are substantially identical, can hardly be distinguished by its appearance from alizarine, which it also resembles in most of its properties. It crystallizes in small orange-colored or red needles. When carefully heated it is almost entirely volatilized, yielding a sublimate of shining orange-colored scales and needles. It is slightly soluble in boiling water, giving a pink solution. It is more soluble in alcohol than in water, the solution having a deep yellow color. It dissolves in concentrated sulphuric acid, and is not decomposed on heating the solution, even to the boiling point. It is decomposed by boiling nitric acid, and yields, like alizarine, phthalic acid. It is distinguished from alizarine, by its solubility in alcohol liquor. When treated with a boiling solution of alum in water, it dissolves entirely, yielding a peculiar opalescent solution, which appears of a bright pink color by transmitted light, and yellowish by reflected light. The solution deposits nothing on cooling, but on adding to it an excess of muriatic acid or sulphuric acid, it becomes colorless, and the purpurine falls down in yellow flocks. On this property depends the method of separating it from alizarine. The compound of purpurine with bases are mostly purple. It dissolves in alkalies with a bright purplish-red or cherry-red color. If the solution in caustic potash or soda be exposed to the air, its color changes gradually to reddish-yellow, and the purpurine contained in it is decomposed, a characteristic which also serves to distinguish purpurine from alizarine, the alkaline solutions of which are not changed by the action of oxygen. The composition of purpurine approaches very near to that of alizarine, but its chemical formula is unknown. It communicates to calico, which has been printed with various mordants, colors similar to those imparted by alizarine, but the red is more fiery, and the black more intense than when alizarine is employed. On the other hand, the purple dyed by means of purpurine has a disagreeable reddish tinge, and presents an unpleasant contrast with the beautiful purple from alizarine. The name of this coloring matter is therefore very inappropriate, and is calculated to mislead. The colors dyed with purpurine are less stable.
than those dyed with alizarine, they are less able to resist the action of soap and other agents than the latter. Hence, very little purpurine is found in combination with the mordants, in such madder colors as have undergone a course of treatment with alkalies and acids, after having been dyed; indeed, the principal object of this treatment appears to be the removal of this and other substances, so as to leave compounds of alizarine only on the fabric. Purpurine seems to abound more in the lower, stronger qualities of madder than in the finer. To this cause, Robiquet chiefly ascribed the superiority of the latter in dyeing fast colors, and no better way of accounting for it has hitherto been suggested. Purpurine forms the basis of the red pigment called madder-red.

Rubiacine is the name which has been applied to a yellow crystallized coloring matter contained in madder. It coincides in most of its properties with the *madder-orange* of Runge. It crystallizes in greenish-yellow lustrous scales and needles. When heated it is entirely volatilized, yielding a crystalline sublimate. It is only slightly soluble in boiling water, but more soluble in boiling alcohol, from which it crystallizes on cooling. It dissolves in concentrated sulphuric acid, and is not decomposed on boiling the solution. It also dissolves in boiling nitric acid without being decomposed. It dissolves in caustic alkalies with a purple color. Its compounds with earths and metallic oxides are mostly red. When treated with a boiling solution of permanganate or permanganic acid it dissolves entirely, yielding a brownish-red solution, which deposits nothing on cooling, but gives, on the addition of an excess of muriatic acid, a yellow flocculent precipitate, consisting of a peculiar acid, called rubiacine acid.

Two amorphous resinous coloring matters, forming brownish-red compounds with bases, have also been obtained from madder. Both are very soluble in boiling water. One of them is a dark brown, brittle, resin-like substance, very easily soluble in alcohol, which melts at a temperature a little above 212° F. The other is a reddish-brown powder, less soluble in alcohol than the preceding. These two coloring matters, together with the sublimate, constitute probably the *tawny* or *dew coloring matter* of the older chemists. They do not contribute to the intensity of the colors dyed with madder, and exert a very prejudicial effect on the beauty of the dyes. If printed calico be dyed with a mixture of alizarine, and any one of these three coloring matters, the colors are found to be both weaker and less beautiful than when alizarine is employed alone. The red acquires an orange tinge, and the purple a reddish hue, whilst the black is less intense, and the parts of the calico which should remain white are found to have a yellowish color. Hence it is of importance to the dyer that their effect should be counteracted as much as possible, by preventing them either from dissolving in the dye-bath or from attaching themselves to the fabric.

The other constituents of madder possess no interest in themselves, but may become of importance in consequence of the effects which they produce during the process of dyeing. The pectin, in the state in which it exists in the root, is probably an indifferent substance, but in consequence of the case and rapidity with which it passes into pectic acid, it may in dyeing act very prejudicially by combining with the mordants and preventing them taking up coloring matter. The extractive matter of madder, when in an unaltered state, produces no injurious effects directly; but by the action of oxygen, especially at an elevated temperature, it acquires a brown color, and then contributes, together with the rubiacine and the resinous coloring matters, in deteriorating the colors and sullying the white parts of the fabric. The extractive matter, when in a state of purity, has the appearance of a yellow syrup, like honey, which is easily soluble in water and alcohol. When pure it is not precipitated from its watery solution by any earthy or metallic salt, but if the solution be evaporated in contact with the air, it gradually becomes brown, and then gives an abundant brown precipitate with sugar of lead. When its watery solution is mixed with muriatic or sulphuric acid and boiled, it becomes green and deposits a dark green powder. Hence this extractive matter has, for the sake of distinction, been called *Chlorogenicum*, and *Rubichloric Acid*. The bitter principle of madder will be referred to presently. The *Xanthine of Kuhlmann*, and the *madder-yellow* of Runge are mixtures of the extractive matter and the bitter principle. The sugar contained in madder is probably grape-sugar. It has not hitherto been obtained in a crystallized state, but it yields by fermentation alcohol and carbonic acid, like ordinary sugar. The woody fibre which is left after madder has been treated with various solvents until nothing more is extracted, always retains a slight reddish or brownish tinge from the presence of some coloring matter which cannot be completely removed, and seems to adhere to it in the same way as it does to the cotton fibre of un-mordanted calico.

There is a question connected with the chemical history of madder which must not be passed over in silence, since it is one which possesses great interest, and may at some future time become of great importance, viz., the question as to the state in which the coloring matters originally exist in the root. It has long been known, that when ground madder is kept tightly packed in casks for some time, it constantly improves in quality for several years, after which it again deteriorates; and it was always supposed that this effect was
due to some process of slow fermentation going on in the interior of the mass, an opinion which seemed to be justified by the evident increase in weight and volume, and the agglomeration of the particles which took place at the same time. Nevertheless, the earlier chemical examinations of madder threw no light whatever on this part of the subject, since the red coloring matters were found to be very stable compounds, not easily decomposed except by the action of very potent agents, so that when once formed it seemed improbable that they would be at all affected by any mere process of fermentation. Hence some chemists were led to the conclusion, that the improvement which takes place in the quality of madder on keeping, is caused by an actual formation of fresh coloring matter. A very simple experiment may indeed suffice to prove that the whole of the coloring matter does not exist ready formed, even in the article as used by the dyer. If ordinary madder be extracted with cold water, the extract after being filtered has generally an acid reaction, and cannot contain any of the coloring matters, since these are almost insoluble in cold water, especially when there is any acid present. Nevertheless, the extract when gradually heated is found capable of dyeing in the same way as madder itself. If the extract be made tolerably strong, it possesses a deep yellow color and a very bitter taste; but if it be allowed to stand in a warm place for a few hours, it gelatinizes, and the insoluble jelly which is formed is found to possess the whole of the tinctorial power of the liquid, which has also lost its yellow color and bitter taste. Hence, it may be inferred that the substance which imparts to the extract its bitter taste and yellow color, is capable also of giving rise to the formation of a certain quantity of coloring matter.

In 1837 a memoir was published by Decaisne, containing the results of an anatomical and chemical examination of the madder plant, experiments which were considered so important that a prize was awarded to the author by the Royal Academy of Sciences of Brussels. This investigation led the author to the conclusion, that the cells of the living plant contain no ready-formed red coloring matter, but are filled with a transparent yellow juice, which, on exposure to the atmosphere, becomes reddish and opaque in consequence of the formation of red coloring matter. Hence he inferred, that the insoluble red coloring matter was simply a product of oxidation of the soluble yellow one, and that, consequently, the more complete the exposure of the triturated root to the atmosphere, the greater would be its tinctorial power; and he even went so far as to assert that all the proximate principles obtained from the root were derived ultimately from one single substance contained in the whole plant. That the fresh roots, before being dried, do indeed contain no coloring matter capable of imparting to mordants colors of the usual appearance and intensity, may be proved by the following experiment:—If the roots, as soon as they are taken out of the ground, are cut into small pieces as quickly as possible, and then extracted with boiling spirits of wine, a yellow extract is obtained which, after being filtered and evaporated, leaves a brownish-yellow residue. Now this residue on being redissolved in water is found incapable of imparting to mordants any but the slightest shades of color; and, on the other hand, the portion of the root left after extraction with spirits of wine, on being subjected to the same test as the extract, is found to possess as little tinctorial power as the latter.

If, however, the roots, instead of being treated with spirits of wine, are macerated in water, the liquor, on being gradually heated, dyes the usual colors as well as ordinary madder. Hence it may be inferred that by means of alcohol the color-producing body of the root may be separated from the agent which, under ordinary circumstances, is destined to effect its transformation into coloring matter, the one being soluble and the other insoluble in that menstruum. It was by this and other similar facts that Schunck was led to an examination of this part of the subject. He infers from his experiments that the color-producing body of madder is identical with its so-called bitter principle, to which he has given the name of Rubian. This body, when pure, has the following properties:—it is an amorphous, shining, brittle substance, like gum, dark brown and opaque in mass, but yellow and transparent in thin layers. Its solutions are of a deep yellow color, and have an intensely bitter taste. It is easily soluble in water and alcohol. The watery solution turns of a blood-red color, on the addition of caustic and carbonated alkalies, and gives dark red precipitate with lime and baryta water. The solution gives a copious light red precipitate with basic acetate of lead, but yields no precipitate with any other metallic salt. On trying to dye with rubian in the usual manner, the mordants assume only the faintest shades of color. If, however, the watery solution be mixed with sulphuric or muriatic acid and boiled, it gradually deposits a quantity of insoluble yellow flocks, which after being separated by filtration and well washed, are found to dye the same colors as those obtained by means of madder. In fact, these flocks contain alizarine, to which they owe their tinctorial power, but they also contain a crystallized yellow coloring matter, similar to, but not identical with rubianine, as well as two resinous coloring matters, which Schunck has named Veratine and Rubellite, and which are probably identical with the resinous coloring matters before referred to as being obtained from ordinary madder. The liquid filtered from the flocks contains an uncrystallizable sugar, similar to that which is obtained from madder itself. Rubian is not decomposed by ordinary fermentations, such as yeast and decomposing casein; but by extract-
ing madder with cold water, and adding alcohol to the extract, a substance is precipitated in pale red flocks, which possesses in an eminent degree the power of effecting the decomposition of rubian. If a watery solution of the latter be mixed with some of the flocculent precipitate, (after having been collected,) and then left to stand in a warm place for some hours, the mixture is converted into a light brown jelly, which is so thick that the vessel may be reversed without its falling out. This jelly, when agitated with cold water, communicates to the latter very little color or taste, proving that the rubian has undergone complete decomposition by the action of the flocculent substance or ferment added to its solution. The cold water, however, extracts from the gelatinous mass a quantity of sugar, while the portion left undissolved contains azalinarie, versantine, rubinine, and a crystalline yellow coloring matter, besides a portion of undecomposed ferment. Rubian, therefore, by the action of strong mineral acids and of the peculiar ferment of madder, is decomposed, yielding sugar and a variety of coloring matters, the principal of which is azalinarie. It appears, therefore, that these coloring matters are not originally contained as such in the root, but are formed by the decomposition of one parent substance, which alone is produced by the vital energies of the plant. In addition to this substance, the plant also contains another, which possesses the property of rapidly effecting the decomposition of the first. The two are, however, during the living state of the plant, prevented from acting on one another, either in consequence of their being contained in different cells, or because the vital energies of the plant resist the process of decomposition. During the drying and grinding of the root, the decomposition of the color-producing body commences, and continues slowly during the period that the powder is kept before being used. It is finally completed during the process of dyeing itself, and hence no trace of color-producing substance can be detected, either in the liquor or the residual madder, after the operation of dyeing is concluded. The presence of oxygen does not seem to be essential during this process of decomposition, as Dechombert supposes, as Schuckers prove by exposing the solution, mixed with some alkali or alkaline earth, to the atmosphere, giving rise to a peculiar acid, called by him rubianic acid. When rubian is heated at a temperature considerably exceeding 212° F., it is converted without much change of appearance into a substance which yields by decomposition resinous coloring matters in the place of azalinarie. The great excess of these coloring matters contained in the madder of commerce arises therefore most probably from the high temperature employed in drying the root.

Employment of Madder in Dyeing.—After the account which has just been given of the composition of madder, it may easily be conceived that the chemical and physical phenomena which occur during the various processes of madder dyeing, are of a rather complicated nature, and that many of these phenomena have not yet received a perfectly satisfactory explanation. Nevertheless, the present state of our knowledge on this subject may enable us to give a consistent explanation of the facts presented to us by the experience of the dyer, and even to indicate what direction our labors must take if we wish to improve this branch of the arts.

In order to produce perfectly fast colors in madder dyeing, it is necessary that the madder should contain a large proportion of carbonate of lime, and if the madder is naturally deficient in that salt, the deficiency may be supplied either by using calcareous water in dyeing, or by adding a quantity of ground chalk. If madder be treated with dilute sulphuric or muriatic acid, so as to dissolve all the lime contained in it, and then washed with cold water until the excess of acid is removed, its tinctorial power will be found to be very much diminished, but may be entirely restored, and even increased, by the addition of a proper quantity of lime-water or chalk. Hence, too, Avignon madder, which is grown in a highly calcareous soil, and contains so much carbonate of lime as to effervesce with acids, affords the most permanent colors; whilst Alsace madder requires the addition of carbonate of lime in order to produce the same effect. This fact was first pointed out by Hausmann, who, after having produced very fine reds at Rouen, encountered the greatest obstacles in dyeing the same reds at Logelbach, near Colmar, where he went to live. Numerous trials, undertaken with the view of obtaining the same success in his new establishment, proved that the cause of his favorable results at Rouen existed in the water, which contained carbonate of lime in solution, whilst the water of Logelbach was nearly pure. He then tried a factitious calcareous water, by adding chalk to his dye-bath. Having obtained the most satisfactory results, he was not long in producing here as beautiful and as solid reds as he had done at Rouen. This simple fact led to the production of a series of lengthy memoirs on the part of some of the French chemists and calico-printers, which fully confirmed the results of Hausmann, without, however, leading to a satisfactory explanation of them. The experiments of Robiquet prove that in dyeing with pure azalinarie the least addition of lime is rather injurious than otherwise, as it merely weakens the colors without adding to their durability. Hence, the beneficial effect of lime can only be accounted for by some action which it exerts on other constituents of the root. Barthold imagined that this action consisted simply in the decomposition of the sulphate of magne-
sia, which he found to be contained in ordinary madder. It was asserted by others, that the carbonate of lime served to neutralize some free acid, supposed by Kuhlmann to be malleic acid, which was present in some madders, and which not only to a great degree prevented the coloring matters from dissolving in the dye-bath, but also combined with the mordants to the exclusion of the latter. Though later researches have failed to detect the existence of malleic acid in madder, still it is certain that all watery extracts of madder contain peptic acid, which probably exists in the root originally as peptic; and that this acid, when in a free state, acts most injuriously in dyeing with alizarine, but ceases to do so as soon as it is combined with lime. Nevertheless, it seems that madder which is naturally deficient in lime, cannot be made to replace entirely such madder as has been grown in a calcareous soil, however great an excess of chalk be used in dyeing. Hence Robiquet was led to the conclusion, that the inferior kinds of madder, which are also the most deficient in lime, contain more purpure and less alizarine than the superior kinds, and that the carbonate of lime serves partly to combine with the purpurine and prevent it from uniting with the mordants, and thus producing less permanent dyes. The experiments of Schunck have proved that not only pectic acid, but also rubiacine and the resinous coloring matters of madder, act detrimentally in dyeing with pure alizarine, by deteriorating the colors and swallowing the white parts of the fabric, and that these effects are entirely neutralized by the addition of a little lime-water to the dye-bath. If in dyeing with madder the whole of the coloring matters were in a free state, the resinous and yellow coloring matters would, according to Schunck, unite with the mordants, to the exclusion of the alizarine, yielding colors of little permanency and of a disagreeable hue; but on adding lime they combine with it, and the alizarine, being less electro-negative, then attaches itself to the mordants or weaker bases. A great excess of lime would of course have an injurious effect by combining also with the alizarine, and preventing it from exerting its titanic power. In practice, a little less lime is added than is sufficient to take up the whole of the impurities with which the alizarine is associated, thus allowing a portion of the former to go to the mordants, to be subsequently removed by treatment with soap and other detergents. Lastly, it has been asserted by Köchlin and Person, that when lime is used in dyeing with madder, the colors produced are not simply compounds of coloring matter with mordants, but contain also in chemical combination a certain quantity of lime, which adds very much to their stability. It is probable that all these causes contribute in producing the effect. The carbonates of magnesia and zinc, acetate and neutral phosphate of lime, and the protoxides of lead, zinc and manganese, act in a similar manner to carbonate of lime in madder dyeing, but are less efficient.

Dambourny and Beckmann have asserted, that it is more advantageous to employ the fresh root of madder than that which has been submitted to desication, especially by means of stores. But in its state of freshness, its volume becomes troublesome in the dye-bath, and uniform observation seems to prove that it ameliorates by age up to a certain point. Besides, it must be rendered susceptible of keeping and carrying easily.

In dyeing printed calicoes with madder, the general course of proceeding is as follows:—

The madder having been mixed in the dye-vessel with the proper quantity of water, and, if necessary, with chalk, the liquid is heated slowly by means of fire or steam, and the fabric is introduced and kept constantly moving, until the dyeing is finished. The temperature should be kept low at first, and should be gradually raised, without allowing it to fall, until it reaches the boiling-point; and the boiling may, if necessary, be continued for a short time. The chief object of the gradual heating seems to be to allow the ferment to exert its full power on the rubian or color-producing body, for this process, like all processes of fermentation, is most active at a temperature of about 100° F., and is arrested at 212° F. In dyeing quickly, less permanent colors are also produced, in consequence, probably, of the coloring matters combining with the more superficial portions of the mordants, and not penetrating sufficiently into the interior of the vegetable fibre. The fastest colors are produced by dyeing at a moderate temperature, and not allowing the liquid to boil. By boiling, the madder becomes more thoroughly exhausted, and a greater depth of color is attained, but the latter resists less perfectly the action of soap and other agents, than the same shade dyed at a lower temperature. The time occupied in dyeing varies according to the nature and intensity of the colors to be produced; but there is little advantage in allowing it in any case to exceed three hours, since the gain in color acquired is more than counterbalanced by the loss of time and increased expenditure of fuel caused by a long-continued ebullition. In dyeing ordinary madder colors, such as red, black, chocolate, and common purple, which do not require much treatment after dyeing, in order to give them the desired tone and intensity, strong but inferior qualities of madder may be used with advantage; and various dyes of similar effect, such as peachwood, peach-blond, sumach, &c., are often added to the madder, in order to give the shade and depth of color. But for the finer colors, such as pink and fine purple, which after dyeing must be subjected to a long course of treatment with soap and acids before they assume the requisite beauty and delicacy of hue, it is necessary to employ the finest qualities of madder; for if dyed with infe-
rior qualities they would resist only imperfectly the requisite after-treatment, and great care must be observed in regulating the temperature during dyeing. The addition of other dye-stuffs, in their case, would be not only useless, but positively injurious. The use of different kinds and qualities of madder in conjunction, is often found to be attended with benefit, arising probably from the circumstance of one kind supplying some material or other, such as ferment or carbonate of lime, in which the other is deficient.

The chemical processes which take place during the operation of dyeing may be shortly described as follows:—In the first place, the water of the dye-bath extracts the more soluble constituents of the madder, such as the sugar, extractive matter, and bitter principle. The latter substance is decomposed by the ferment, and the coloring matter thereby formed is added to that which already exists in the root. As the temperature rises, the less soluble constituents, such as the aizazine, purpurine, rubiaine, the resinous coloring matters, the pectic and peletic acid, begin to dissolve, and as they dissolve they combine partly with the mordants of the fabric, partly with the lime and other bases contained in the root or added to the dye-bath, and thus permit the liquid to take up fresh quantities from the madder. If the quantity of madder was exactly proportioned to the quantity of fabric to be dyed, then it becomes, in this way, gradually exhausted of all available coloring matter. The extractive matter at the same time acquires a brown color by the combined action of the heat and oxygen, and covers the whole surface of the fabric with a uniform brown tinge. When the dyeing is concluded, the liquor appears muddy and of a pale dirty red color. It still contains a quantity of coloring matter in a state of combination with lime and other bases from the madder, or with portions of the mordant mechanically detached from the fabric. The residual madder at the bottom of the liquor and contains a quantity of coloring matter in a similar state of combination. By mixing the residue and the liquor with sulphur or muriate acid, boiling, and then washing with water, the various bases are removed, and the coloring matter is thus made available for dyeing. Occasionally, when a very great depth of color is required, it is found advisable to let the goods pass through a second dyeing operation, instead of obtaining the requisite shade at once.

After the calico has been removed from the dye-bath and washed in water, it presents a very unsightly appearance. The alumina mordant has acquired a dirty brownish-red color, and the iron mordant a black or brownish purple, according to its strength, whilst the white portions are reddish-brown. In the case of ordinary colors, the fabric is now passed through a mixture of boiling bran and water, or through a weak solution of chloride of lime, or it is exposed for some time on the grass to the action of air and light, or it is subjected to several of these processes in succession, by which means the impurities adhering to the mordants or the fibre are, in a great measure, either removed or destroyed, the white portions recovering their purity, and the red, black, purple, and chocolate, appearing afterwards sufficiently bright for ordinary purposes. That the colors, however, even after being thus treated, still contain in combination with the mordants other substances in addition to the various dyeing matters, may be proved by a very simple experiment. It is a very small part of some calico, which has been treated as just described, be immersed in dilute muriatic acid in the cold, the mordants are removed, and the colors are destroyed; orange-colored stains being left on the places where they were before fixed. After washing the calico with cold water, the orange-colored matter may be dissolved in alkali, and the calico left entirely white. The solution which is brownish-red, gives, with an excess of acid, a reddish-brown flocculent precipitate. This precipitate, after being collected on a filter and well washed with water, is found to be only partially soluble in boiling alcohol, a brown substance, consisting partly of peetric acid, being left undissolved. The yellow alcoholic solution leaves, on spontaneous evaporation, a brown crystalline residue, which is found on examination to contain aizazine, purpurine, a little rubiaine, or some similar compound, and a brown amorphous substance. The removal of these various impurities, associated with the aizazine, seems to be the principal object of the treatment to which madder colors are subjected, when it is desired to give them the highest degree of brilliancy of which they are susceptible. This course of treatment, as applied to printed calicoes, may be shortly described as follows:—The goods, after being very fully dyed, generally with the addition of chalk, and then washed, are passed for some time in a solution of soap, which is heated to a moderate temperature. By this means a great deal of color is removed, as may be seen by the red tinge of the soap-liquor, and the purity of the white portions is almost entirely restored. During this process the brown and yellow coloring matters are probably removed by double decomposition, the alkali of the soap combining with and dissolving them, while the fat acid takes their place on the fabric. After being washed, the goods are passed through a weak solution of acid, mostly sulphure or oxalate acid, or an acid tin salt, which causes the colors to assume an orange tinge. The point at which the action of this acid liquid is to be arrested can only be ascertained by practice. The next step in the process is, after washing the goods, to treat them again with soap liquor, which is gradually raised to the boiling point, and they are lastly subjected to the action of soap liquor in a close vessel under pressure. By exposing the goods on the grass for some time after the first
soaping, the use of acid may be obviated, but the process then becomes much more tedious. In this way are produced those beautiful pinks and lilacs, which, for delicacy of hue, combined with great permanence, are not surpassed by any dyed colors known in the arts. Whether the fat acid of the soaps employed forms an essential constituent of these colors is not certainly known, but it is probable that it contributes to their beauty and durability. It is certain, however, that they always contain fat acid. If a piece of calico which has gone through the process just described be treated with mordant acid, the color is destroyed, and a yellow stain is left in its place. This yellow stain disappears on treating the calico, after washing with water, with alkali, yielding a solution of a beautiful purple color. This solution gives again with an excess of acid a yellow flocculent precipitate, which, after filtration, dissolves almost entirely in boiling alcohol, and the solution on evaporation affords needle-shaped crystals of pure aizcurine, mixed with white masses of fat acid. The latter, therefore, seems to occupy the place taken up by the impurities before the treatment with soap. This experiment serves also to prove that it is aizcurine which forms the basis of the more permanent colors afforded by madder, though, on the other hand, as in dyeing the finer madder colors, it cannot be denied that the coloring matters which are removed by the treatment with soap and acids contribute to the effect produced in dyeing ordinary madder colors.

The same result is attained in dyeing Turkey red, but the process employed is somewhat different, and much more complicated. The attempts which have been made at various times to obtain an extract of madder, capable of being applied in making so-called steam colors for calico and other fabrics, have not been completely successful. A very beautiful pink has been produced by Gastard and Girardin, of France, by painting on calico, previously prepared with some mordant, an aqueous solution of an extract of madder, called colorine, but it is not much superior, either as regards its hue or its degree of permanency, to what can be obtained by easier processes from dyewoods and other materials.

Madder is not so much employed in woollen dyeing, especially in this country, as in cotton dyeing and printing. Only ordinary woollen goods are dyed red with madder, since the color is not so bright as that obtained from cochineal or lac, though it is more permanent and cheaper. A mixture of alum and tartar is employed as a mordant. The addition of a little muriate of tin in dyeing, imparts to the color a more scarlet tinge. The bath of madder, at the rate of from 8 to 16 ounces to the pound of cloth, is heated to such a degree as to be just bearable by the hand, and the goods are then dyed by the wince, without heating the bath more until the coloring matter is fixed. Vitellis prescribes as a mordant, one-fourth of alum and one-sixteenth of tartar; and for dyeing, one-third of madder, with the addition of a twenty-fourth of solution of tin, diluted with its weight of water. He raises the temperature in the space of one hour to 200°, and afterwards he boils for 3 or 4 minutes—a circumstance which is believed to contribute to the fixation of the color. The bath, after dyeing, appears to contain much yellow coloring matter. Sometimes a little acriol is added to the madder, in order to give the dye a pink tinge; but the effect is not lasting. By passing the goods after dyeing through weak alkali, the color acquires a bluish tinge. By adding other dyestuffs, such as fistick, peachwood and logwood, to the madder in dyeing, various shades of brown, drab, &c, are obtained. Madder is also used in conjunction with wood and indigo in dyeing woollen goods blue, in order to impart to the color a reddish tinge.

Silk is seldom dyed with madder, because cochinilla affords brighter tints. Preparations of Madder.—The numerous analytical investigations of madder, undertaken chiefly in consequence of the Société Industrielle de Mulhouse having offered in the year 1826 a premium for a means of discovering the real quantity of coloring matter in the root, and of determining the comparative value of different samples of madder, led to many attempts on the part of chemists to improve the quality of this dye-stuff by means of chemical agents, and thus render it more fit for the purposes to which it is applied. Robiquet and Persoz were the first to point out the advantages which result from submitting madder, previous to its being used, to the action of strong acids. They showed that, by acting on madder with strong sulphuric acid, and then carefully washing out the acid with water, a product was obtained, which not only possessed a greater fixatorial power than the original material, but also dyed much brighter colors. This important discovery, which was not, like so many others, arrived at by chance, but was purely the result of scientific investigations, did not at first receive, on the part of practical men, the appreciation which it deserved. The product, obtained by the action of sulphuric acid on madder, which in the first instance was called carbon sulfureux, afterwards garance, was first manufactured on a large scale by M. Lorier and Thomas of Avignon, but so great were the prejudices entertained by dyers and calico-printers against its use at the commencement, that years elapsed before they could be overcome; indeed, they were partly justified by the imperfect nature of the product itself. The persevering efforts to improve the method of manufacture, and adapt it to the wants of the consumer, were at last attended with success, so that
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at the present day garance has come to be used to as great an extent as madder, and large quantities are now manufactured in France and other countries.

It was supposed by Robiquet, that by the action of sulphuric acid on madder, the saccarose, mucilaginous, and extractive matters of the root were destroyed, and thus hindered from producing any injurious effects in dyeing, and that the woody fibre was at the same time charred, so as to prevent it from attracting and binding any of the coloring matter.

This explanation is not entirely correct, since it is not necessary to carry the action so far as actually to carbonise any of the constituents of the root, and it is also doubtful whether the woody fibre ever attracts the useful coloring matters in any considerable degree. The account above given of the chemical constitution of madder, may easily lead us to the conclusion, that during the action of the acid, the following processes take place:—1. The bitter principle or color-producing body of the root is decomposed, yielding, among other products, a quantity of alizarine which did not previously exist. 2. The red coloring matters are rendered by the acid insoluble in water, and thus it becomes possible to wash out the extractive matter, sugar, &c., without the madder losing any of its tinctorial power.

3. The lime, magnesia, and other bases which are combined in the root with coloring matter, or would combine with it during the dyeing process, are removed by the acid, and thus prevented from exerting any injurious action. The subsequent addition of a suitable quantity of lime, soda, or other base, serves to neutralize the effect of the excessive amount of peecic acid and resinous coloring matters, which were set free by the action of the mineral acid.

The method of manufacturing garance, as practised at the present day, may be shortly described as follows:—The ground madder is mixed with water, and the mixture is left to stand for some hours. During this time it is probable that the rubrin is decomposed by the ferment of the root, otherwise a great loss would be experienced. More water is now added, in order to remove all the soluble matters, and is then run off. The liquid contains sugar, and is employed on the condition of this preparation affording the means of an account of its peculiar smell and flavor, cannot be consumed as a beverage, but is used in the arts for the preparation of varnishes and other purposes. A sufficient quantity of alcoholic spirit is thus obtained to pay for the whole cost of the process. The residue left after washing the madder may be employed for dyeing without any further preparation, and is then called fleur de garance. In order to convert it into garance, it is mixed with sulphuric acid, and is employed on the condition that for every pound of root, 2 lbs. of sugar, 50 lbs. of sulphuric acid, and a like quantity of water, are employed in a large boiler, to which is added gradually a large quantity of water, and the liquor is exposed to a temperature of 160°. The sugar is then ground to a fine powder, and this process is repeated until the excess of acid is removed. The peecic acid of the root always retains a portion of the sulphuric acid in chemical combination; and the compound being but little soluble in water would require for its removal a very long washing. The addition of a small quantity of carbonate of soda, by neutralizing this double acid, serves to abridge the time of washing very considerably. The residue is then filtered on strainers, pressed, dried, and lastly ground into a fine powder. The powder has a dark reddish-brown color, and a peculiar odor, different from that of madder, but no taste. It communicates hardly any color to cold water. Dyeing with garance is attended with the following advantages:—

1. The whole tinctorial power of the madder is exerted at once, and garance is therefore capable of dyeing more than the material from which it is made. 2. The colors produced by it, when fresh, are much brighter than those dyed with madder, and the parts of the fabric destined to remain white attract hardly any color, so that very little treatment is required after dyeing. 3. Much less attention is required in regard to the temperature of the dye-bath, and its gradual elevation, than with madder, and a continued ebullition produces no injurious effects, but only serves to exhaust the material of all its coloring matter. On the other hand, garance colors are not so fast as madder colors; they do not resist so well the action of soap and acids, and hence garance cannot be employed for the production of the more permanent colors, such as pink and fine purple. By the use of a product which was patented by Pincoffs and Schunk several years ago, and which is obtained by exposing garance to the action of steam of high pressure, it is indeed possible to dye as beautiful and as permanent a purple as with madder, and its use is attended by a considerable saving of time as well as of dyeing material and soap, but it is not so well adapted for dyeing pink. As yet, therefore, we have not succeeded in obtaining a preparation which shall serve as a perfect substitute for madder, and the latter consequently continues to be employed for some purposes.

The residue left after dyeing with madder, as well as the dyeing liquor, still contain some coloring matter, in a state of combination, as mentioned above. By acting on it with sulphuric acid, it affords a product similar to garance, which is called garance. This product is, however, adapted only for dyeing red and black, as it does not afford a good purple. Numerous other methods of treating madder for the use of the dye have been invented and patented of late years, but they are not sufficiently important to merit description within the limits of the present article.

MAHOGANY: The wood of a tree (Swietenia mahogoni) which is a native of the West Indies. This wood appears to have been first brought to England in 1724.
MAHOGANY.

SPANISH mahogany is imported from Cuba, St. Domingo, the Spanish Main, and several of the West India Islands, in logs about 26 inches square and 10 feet long. Its general character is well known, from its extensive use in cabinet work.

HONDURAS mahogany is generally lighter than the Spanish, and more open and irregular in its grain. This is imported in large logs, many of 4 feet square and 18 feet in length. Planks are sometimes obtained of 7 feet in width. According to Mr. Chief-Justice Temple, "the cutting commences in the month of August. In April or May, when months the ground has become perfectly hard from the continued dry weather, the wood is carried upon trucks drawn by bullocks to the water side, and about the middle of June, when the rivers are swollen by the floods, the logs are floated down about 10 miles from the mouths of the different rivers, where they are confined by a heavy boom drawn across the stream. Here the owners select their respective logs from them into rafts, and so float them down to the sea. The mahogany is always trucked in the middle of the night, the cattle not being able to perform such laborious work during the heat of the day. It is a picturesque and striking scene, this midnight trucking. The lowering of the oxen, the breaking of the wheels, the shrill cries of the men, the resounding cracks of their whips, and the red glare of the pine torches, in the midst of the dense dark forest, produce an effect approaching to sublimity."

An impression has latterly existed that almost all the mahogany in British Honduras has been cut. This, however, is a mistake. There is sufficient wood in the country, both on granted and ungranted land, to supply the European as well as the American markets for many years to come. A considerable quantity of mahogany has been, within the last few years, cut in the state of Honduras and on the Mosquito shore; but the mahogany works in the former country have been almost entirely abandoned, partly on account of the wood which is accessible, being mostly all cut, and partly on account of the freight and insurance which are required when vessels are loaded on that coast. From the Mosquito shore very few cargoes have been lately sent, for the wood which grows there, although it is very large, is of inferior quality. The mahogany tree requires a rich dry soil. The best mahogany is found to the north of the river Belize. In consequence of the nature of the soil in that district, in which there is a great quantity of limestone, the mahogany is longer coming to maturity, but, when fully grown, it is of a harder and firmer texture than that which is found in the southern portion of the settlement. There is no wood more durable than mahogany, and none that is so generally useful. It is stated in a little book called "The Mahogany Tree," that furniture is being made, in the royal dockyards, out of the beautiful mahogany found in breaking up the old line-of-battle ship the "Gibraltar," which was built in Havana 100 years ago. The English and French governments purchased yearly a large amount of mahogany for their dockyards. During the last year the British government required 12,000 tons, paying £10 17s. 6d. per ton. The French government took 3000 tons at the same price. The royal yacht is built principally of Honduran mahogany. Private shipbuilders are, however, reluctant to make use of mahogany for their vessels, as Lloyd's Committee exclude all ships of 12 years' standing, in which the floors, futtocks, top timber, keelson, stem and stern post, transoms, knight's heads, bawse timbers, apron, and dead wood are made of mahogany.

Mahogany vessels of 10 years' standing they admit, but even these, I am informed, it is their intention very shortly to exclude. The reason which they assign is, that mahogany differs very much in quality, and it is impossible to know when a ship is built of good or bad wood. But this difference in quality depends entirely upon the district in which it has grown. If they restricted the shipbuilders to the northern wood, they might admit vessels of 12 years' standing without any risk. In the year 1846 the Honduras merchants presented a memorial to Lloyd's Committee, praying for a removal of the existing limitations to the general use of mahogany in the building of vessels of the highest class. Attached to this memorial, were numerous certificates from persons well qualified to give an opinion on the subject, speaking in the highest terms of mahogany for shipbuilding. Captain R. Chap- pel, R.N., Secretary of the Royal Mail Steam-Packet Company says he has seen the "Gibraltar," 50-gun ship, which was broken up at Pembroke. This ship is entirely of mahogany; captured of the Spaniards in 1780, all her timbera sound as when put into her. Tables for the navy made of the timbers of the Gibraltar. The Steamer Forth, built by Mr. Menzies of Leith, has as much mahogany put into her as could be obtained. The use of mahogany ought to be the rule, and not the exception. The qualities of mahogany, which render it so peculiarly fitted for shipbuilding, are its lightness and buoyancy, its freedom from dry rot, and its non-liability to shrink or warp. The price of mahogany varies according to the size, figure, and quality of the wood. One tree from the northern districts, which was cut into three logs, sold for £1800, or 10s. per superficial foot of 1 inch; southern wood of smaller size and inferior quality has been sold at £1d. a foot. The present prices in London for small-size plain mahogany are 6d. to 6s. per foot; for large-size plain, from 7d. to 10s.; and for large, of good quality and figured, from 9d. to 1s. 6d.

The yearly average quantity of mahogany exported from Honduras during the last
ten years is about eight millions of feet, equal to 20,000 tons, or 200,000 tons in the whole ten years, requiring 160,000 trees."

MALM ROCK. A local name for the sandstones of Surrey and Sussex, called also fire stone.

MAMMER. A tree growing in Honduras. Its dried leaves are very powerfully narcotic; the bark is, however, stated to possess some tonic properties. The flowers of the tree are used in flavoring a liqueur made in some parts of the West Indies called crême des crocodiles.—Temple.

MANCHINEEL. A large tree of a very poisonous character, growing in South America, and in some parts of the West Indies. The wood is of a yellow-brown color, beautifully clouded, and very close and hard. It is sometimes used instead of mahogany.

MANDIOCA. Cassava starch. See Starch.

MANURE, ARTIFICIAL. Agricultural writers usually divide manures into two classes, natural and artificial.

The first division includes farmyard manure, liquid manure, and the various composts that are occasionally made by farmers from excrementitious matters, earth, lime, and all sorts of refuse matters found or produced on the farm.

In the second division we find guano, bone dust, nitrate of soda, sulphate of ammonia; also the waste of slaughter-houses, night-soil, the refuse of glue-makers, wool waste, and other refuse materials of certain factories; and likewise superphosphate of lime, blood, manure, and a great variety of saline mixtures, which are now extensively manufactured in manure works, for the purpose of supplying farmers with special chemical fertilizers, such as wheat-, barley-, oat-, potato-, flax-manure, &c. The term artificial manure thus includes a great variety of different materials, and is frequently applied to products which, like guano, are in point of fact much more natural than farmyard manure, in the successful preparation of which a certain amount of skill is required on the part of the farmer. The evident anomaly of considering guano, bones, blood, and nitrate of soda (Chili salpetre) as artificial manures, has led some agricultural writers to describe them under natural manures. Again, other artificial manures are but the most extensively used artificial manures, such as wheat and grass manures, or to manures the preparation of which necessitates a certain acquaintance with chemical principles and the use of chemical agents. All this confusion can be avoided entirely, if manures, instead of being divided into natural and artificial, were separated into home-made manures, that is, manures produced from the natural resources of the farm, and into imported manures, that is, fertilizers which are introduced on the farm from foreign sources.

The term "artificial," more appropriately, is given to all simple or compound fertilizers in the production of which human art has been instrumental. In this signification we shall use the term artificial manure.

Not many years ago farmyard manure was universally considered the only efficient fertilizer to restore the fertility of land, impaired by a succession of crops. Recent agricultural experience, however, has shown that, in a great measure, artificial manures may be employed with advantage instead of yard manure, nay, that in several respects artificial manures are preferable to ordinary dung. Indeed the present advanced state of British agriculture is intimately connected with the success with which artificial manures have been introduced into the ordinary routine on the farm.

The variety of artificial manures in present use amongst English farmers is very great. Some, like well prepared samples of superphosphate, are unquestionably manures distinguished for high fertilizing properties; others are less efficacious, or of a doubtful character; and not a few hardly repay the cost of carriage beyond a distance of 10 miles. The fact that in almost every market-town artificial manures are sold, which, if not altogether worthless, offer, to say the least, no profitable investment to the occupier of land, shows plainly that the principles which ought to regulate the manufacture of artificial manures are not so generally understood as it is desirable they should be. In comparison with other branches of industrial art, the manufacture of manures is comparatively simple, and involves no very expensive machinery beyond steam power for the pulverization of the raw materials; nor does it necessitate extensive practical experience, or the possession of a large stock of chemical knowledge, on the part of the manufacturer. The limits of this article preclude the detailed description of all the artificial manures that find their way at present into the manure market; nor does it appear to us necessary to mention in detail the various proportions in which the numerous refuse materials used by manure-makers may be blended together into efficacious fertilizers, for a manufacturer who is thoroughly acquainted with the nature of artificial manures, and the legitimate uses to which they ought to be applied, will find little or no difficulty when working up into artificial manures the raw materials or refuse matters, for the acquirement of which a particular locality may offer peculiar advantages. A right conception of the relative commercial and agricultural value of the different constituents that enter into the composition of manures is the chief desideratum for the manufacturer of artificial manures. We therefore propose to refer, in the following pages, briefly to the
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more important principles which ought to be kept steadily in view in establishments erected for the supply of artificial fertilizers.

The high esteem in which good farmyard manure is held by practical men, its uniformly beneficial effect upon almost every kind of crop, and the economical advantages with which it is usually applied to the land, have induced many to regard farmyard manure as the model which the manufacturer of artificial manure should endeavor to imitate. But this proposition is wrong in principle, as will be shown presently, and its adoption in manure works has led to disappointment and ruin. It would be foreign to our object to give in this place a full account of the peculiar merits that belong to yard manure, and to compare them with those exhibited by artificial manures. Each has its peculiar merits and disadvantages, upon which we need not dwell in this article.

Farmyard manure contains all the constituents which our cultivated crops require to come to perfection, and is suited for every description of agricultural produce. As far as the inorganic fertilizing substances are concerned, we find in farmyard manure potash, soda, lime, magnesia, oxide of iron, phosphoric acid, sulphuric acid, hydrochloric and carbonic acid, in short all the minerals that are found in the ashes of agricultural crops.

Of organic fertilizing substances, we find in farmyard manure some which are readily soluble in water, and containing a large portion of nitrogen; and others insoluble in water, and containing, comparatively speaking, a small proportion of nitrogen. The former readily yield ammonia, the latter principally give rise to the formation of Humic acids, and similar organic compounds. These organic acids constitute the mixture of organic matters, which in practice pass under the name of humus.

Farmyard manure thus is a perfect manure, for experience and analysis alike shows that it contains all the fertilizing constituents required by plants, in states of combination which appear to be especially favorable to the luxuriant growth of our crops.

On most farms, the supply of common yard manure is inadequate to meet the demands of the modern system of high farming. Hence the endeavor of enterprising men to supply this deficiency by converting various refuse materials into substitutes for farmyard manure. Artificial manures, likely to approach farmyard manure in their action, should contain all the elements in the latter, and in a state of combination, in which they are neither too soluble nor too insoluble; for it is evident that a plant can grow luxuriantly, and come to perfect maturity, only when all the elements necessary for its existence are presented to it in a state in which they can be assimilated by the plant.

But the question arises, Is it desirable to produce by art perfect substitutes for common dung? We think not, for the following reasons:

In the first place, well rotted dung contains in round numbers two thirds of its weight of water, and only one third of its weight of dry matter. A large bulk therefore contains, comparatively speaking, but a small proportion of fertilizing matters. In every 3 tons of manure we have to pay carriage for 2 tons of water, and it may be safely asserted that no manure, however efficacious it may be in a dry condition, will be found an economic substitute for farmyard manure, if it cannot be produced in a much drier condition than common yard manure.

Again, several of the constituents which greatly preponderate in farmyard manure are present in most soils in abundant quantities; they need not, therefore, be supplied to the land in the form of manure; or, should they be wanting in the soil, they can be readily obtained almost everywhere at a cheap rate. If, therefore, these inexpensive and more widely distributed substances are dispensed with in compounding a manure, and those are selected which occur in soils only in minute quantities, a very valuable and efficacious fertilizer is obtained, which possesses the great advantage of containing in a small bulk all the essential fertilizing substances of a large mass of home-made dung.

That the effect which every description of manure is capable of producing depends on its composition is self-evident; and as the different constituents which generally enter into the composition of manures produce different effects upon vegetation, it is of primary importance to the manufacturer of manure that he should be acquainted with the special mode of action of each fertilizing constituent.

We shall therefore make some observations on the practical effects, and the comparative value, of the various constituents that enter into the composition of manures.

To guard against misapprehension, we would observe that, in one sense, all the fertilizing agents are alike valuable; for they are all indispensable for the healthy condition of our cultivated crops, and, consequently, the absence of one is attended with serious consequences, though all others may be present in abundance. Thus the deficiency of lime in the land is attended with as much injury to the plant as that of phosphoric acid. In this sense lime is as valuable as phosphoric acid; but inasmuch as lime is generally found in most soils in abundant quantities, or, if deficient, can be applied to the land economically in the form of slacked lime, marl, shell sand, &c., its presence in an artificial manure is by no means a recommendation to it.

The principal constituents of Manures are:
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1. Nitrogen.—This element may be incorporated with artificial manures in the shape of ammonical salts or nitrates, or nitrogenized organic matters. The cheapest ammonical salt is sulphate of ammonia; the cheapest nitrate is Chili salt-petre, or nitrate of soda; hence sulphate of ammonia and nitrate of soda are exclusively employed by manure manufacturers for the preparation of nitrogenized manures, when no organic refuse matters containing nitrogen, such as horn-shavings, bone-dust, woolen rags, blood, glue refuse, &c., are available.

Nitrogen in any of these forms exercises a most powerful action in manure, especially when applied to plants at an early stage of their growth; at a later period of development the application of ammonical salts or nitrate of soda appears much less effectual, and sometimes even useless. For this reason nitrogenized manures, such as guano, soot, specially prepared wheat manures, &c., ought to be applied either in autumn or in spring, immediately after the young blade has made its appearance above ground.

Ammonical salts, nitrate of soda, and decomposed nitrogenized organic matters have a most marked effect upon the leaves of plants, they induce a rapid and luxuriant development of the leaves, and may therefore be called leaf-producing or forcing manures. Grass, wheat, oats, and other cereals, when grown upon soils containing abundance of available mineral elements, are strikingly benefited by a nitrogenized manure; but, on account of their special action, they ought to be used with caution in the case of corn-crops, and always more sparingly on light than on heavy land; otherwise, fine straw, but little and an inferior sample of grain, will be obtained.

As a general rule, ammonical salts or nitrate of soda should not be used by farmers in a concentrated state, and exceptionally only. However useful sulphate of ammonia or nitrate of soda may be in a particular case, it ought to be remembered that generally such manures produce beneficial effects only in conjunction with mineral matters. If, therefore, a proper amount of available mineral substances does not exist in the soil, it has to be supplied in the manure. Ammonical salts, nitrate of soda, animal matters, &c., are therefore almost always blended together with phosphates, common salt, gypsum, &c., by manufacturers of manures.

Whilst we thus fully recognize the importance of the presence of ammonia, ammonical salts, nitrates, or animal matters furnishing ammonia on decomposition in manures, especially in manures for white crops, we cannot agree with those who estimate the entire value of manuring substances by the proportion of nitrogen which they contain.

In a purely commercial sense, nitrogen in the shape of ammonia or nitric acid, or animal nitrogenized matters, is the most valuable fertilizing constituent, for it fetches a higher price in the market than any other manuring constituent.

2. Phosphoric acid.—Next in importance follows phosphoric acid. This acid exists largely in the grain of wheat, oats, barley, in leguminous seeds, likewise in turnips, mangolds, carrots, in clover, meadow-hay, and, in short, in every kind of agricultural produce. Whether we grow, therefore, a cereal crop or a fallow crop, there must be phosphoric acid in sufficient quantity in the soil, or if insufficient it must be added to the land in the shape of manure.

The proportion of phosphoric acid in even good soils is very small, and as the agricultural produce in almost every case removes from the soil more of phosphoric acid than of any other soil-constituent, the want of available phosphoric acid makes itself known very soon. This is especially the case with quick-growing crops, such as turnips, mangolds, &c. The whole period of vegetation of these green crops extends only over four or five months, and the fibrous roots of these crops are unable to penetrate like wheat the soil to any considerable depth. For these reasons phosphoric acid in some form or other has to be abundantly supplied to root-crops; and experience has shown that no description of fertilizing matter benefits so much roots as super-phosphate and similar manures, which contain phosphate of lime in a state in which it is readily assimilated by plants.

In artificial manures, phosphoric acid commonly occurs in the shape of bone-dust, boiled bones, bone-shaving (refuse of knife-handle makers, turners of Ivory, button-makers, &c.), or in the state of bi-phosphate of lime, purposely manufactured from bone-materials or from phosphatic minerals.
The phosphate of lime which occurs in fresh bone, practically speaking, is insoluble in water. In water charged with carboxylic acid, and still more so in water containing some ammonia, it is more soluble than in pure water. On fermenting bone-dust in heaps, it becomes a much more effective manure. Such fermented bone-dust is added with much benefit to general artificial manures.

All really good artificial manures should contain a fair proportion of phosphate—say from 25 to 40 per cent., according to the uses for which the manure is intended. Generally speaking, manures for turnips, and root-crops in general, should be rich in phosphates, especially soluble phosphates; (bi-phosphate of lime,) such manures need not contain more than 1 to 1 1/2 per cent. of ammonia, and, when used on land in a tolerably good agricultural condition, ammonia can altogether omitted in the manure without fear of deteriorating the efficacy of the manure.

5. Potash.—Salts of potash unquestionably are valuable fertilizing constituents, for potash enters largely into the composition of the ashes of all crops. Root-crops especially require much potash; hence these crops are much benefited by wood ashes, burnt clay, liquid manure, and other fertilizers containing much potash.

The commercial resources of potash are limited, and salts of potash without exception far too expensive to be employed largely in the manufacture of artificial manures. Potash consequently is rarely found in artificial manures. Fortunately, potash exists abundantly in most soils containing a fair proportion of clay. Its want in artificial manures therefore is not perceived, at least not in the same degree in which the deficiency of phosphates in a manure would be felt.

4. Soda.—Salts of soda are much less efficacious fertilizing matters than salts of potash. There are few soils which do not contain naturally enough soda, in one form or the other, to satisfy the wants of the crops which are raised upon them. However, common salt is largely employed in the manufacture of artificial manures; if it does no good, it certainly does no harm, and in this country is one of the cheapest diluents which can be employed for reducing the expenses of concentrated fertilizing mixtures to a price at which they can be sold to farmers. In Continental districts common salt proves more efficacious as a manure than in England, where the neighborhood of the sea provides the majority of soils with plenty of salt, which by the winds is carried landwards with the spray of the sea to very considerable distances.

Salt, however, even in England, is usefully applied to mangolds, and enters largely into the composition of most artificial manures expressly prepared for this crop.

5. Lime and Magnesia.—All plants require lime and magnesia in smaller or larger quantities. Many soils contain lime in superabundance; in others it is deficient. To the latter soils it must be added. This can be done by lime-compost, by slaked lime, by marl, shell-sand, or gypsum. All these calcareous manures are cheap almost everywhere, for lime and magnesia are among the most widely distributed, and most abundant mineral substances.

The addition of chalk, marl, and even gypsum, to artificial manures, should therefore be avoided as much as possible.

At the best, carbonate and sulphate of lime in artificial manures must be regarded as diluents.

6. Soluble Silica. The artificial supply of soluble silica to the land, as far as our present experience goes, has done no good whatever to cereals, the straw of which soluble silica is supposed to strengthen.

In the absence of reliable practical experiments with soluble silica, we cannot venture to recommend the use of silicate of soda, or soluble silica to manure manufacturers.

7. Organic substances, Humus.—The importance of organic matters free from nitrogen, as fertilizing agents, is very trifling. Formerly the value of a manure was estimated by the amount of organic matter it contained, and little or no difference was made whether the organic matter contained nitrogen or not. Under good cultivation, the organic matter in the soil regularly increases from year to year; there exists therefore no necessity of supplying it in the shape of manure.

In artificial manures we should certainly exclude all substances that merely add to the bulk, without enhancing the real fertilizing value of the manure. Peat, saw-dust, and similar organic matters, &c., are useful to the manure-maker only as diluents and absorbents of moisture.

8. Sulphuric acid is another constituent of manure, which possesses little value. In artificial manures sulphuric acid chiefly occurs as gypsum.

9. Chlorine exists in manures principally as salt.

10. Oxide of iron, Alumina, Silica.—These constituents exist sometimes in manures in the shape of burnt-clay, earth, brick-dust, and sand.

It is hardly necessary to remark that good artificial manures should contain as little as possible of these matters.

It will appear from the preceding observations, that nitrogen in the shape of ammoniacal salts, nitric acid or decomposed animal matters, and phosphoric acid are the most valuable fertilizing constituents.
The manufacturers of artificial manures should therefore endeavor:
1. To produce manures containing as little water as possible.
2. To incorporate as much of nitrogenized organic matters, or ammoniacal salts, or nitrates and phosphates, in general manuring mixtures, as is possible at the price at which artificial manures are usually sold.
3. To avoid as much as possible, gypsum, salt, peat-mould, chalk, and other substances that chiefly add to the bulk, without increasing the efficacy, of the manures.

He should also endeavor to produce uniform finely pulverized articles, that run readily through the manure drill.

It likewise devolves on the manufacturer of manures to render more effective, that is to say, more rapid and energetic in their action, refuse materials which may remain inactive in the soil for years before they enter into decomposition, and to reduce by chemical means into a more convenient state for assimilation, raw materials, which like coprolites, apatite, &c., produce little or no beneficial effects upon vegetation, even when added to the land in a finely powdered condition.

At the present time, two classes of artificial manures may be distinguished: 1, general manures, i.e., manures which profess to suit equally well every kind of agricultural produce; and 2, specially prepared for a particular crop only.

The requirements of different crops, or perhaps, more correctly speaking, the conditions that regulate the assimilation of food, vary so much, that we doubt the policy of manure-makers to prepare general artificial manures. At the same time, we doubt the necessity of preparing artificial manures for every description of crop. Special manures are extremely useful to farmers, if they are prepared by intelligent manufacturers, who possess sufficient chemical knowledge to take advantage of every improvement that is made in manufacturing chemistry, and at the same time know sufficient of agriculture to understand what is really wanted in a soil. In other words, except a manufacturer is a good practical chemist, and a tolerably good farmer, he will not be able properly to adapt the composition of special fertilizers to the nature of the soil, and the peculiar mode of treatment which the land has received on the part of the farmer.

However, nearly all special artificial manures, generally speaking, may be arranged under two heads. They are either: 1. Nitrogenized Manures, or, 2. Phosphatic Manures.

The first may be used with almost equal advantage for wheat, barley, oats, for rye, and on good land likewise for grass.

The second are chiefly used for root-crops.

Nitrogenized artificial manures frequently are nothing more than guano, diluted with gypsum, salt, peat-mould, earth, &c. In fact, guano is the cheapest ammonial manure, for which reason it is so largely employed for compounding low-priced wheat manures, grass manures, &c., &c.

Good manures for cereals may be made by blending together fine bone-dust, or bone-dust dissolved in sulphuric acid, sulphate of ammonia, salt and gypsum. These manures will be the better the more sulphate of ammonia they contain.

Turnip-manures, and artificial manures for root-crops in general, consist principally of dissolved bones, or dissolved coprolites and other mineral phosphates. They are, in fact, superphosphates of various degrees of concentration. The more soluble phosphate a root-manure contains, the better it is adapted to the purpose for which it is used.

Most samples of superphosphate contain little or no ammonia, or nitrogenized organic matters.

Others sold under the name of nitro- or ammonia-phosphate, in addition to soluble and insoluble phosphate, contain some ammonia and organic matters.

Blood manure is a superphosphate, in the preparation of which some blood is used.

In preparing superphosphate from bones, it is essential that they should be reduced to fine dust. This is moistened with about \( \frac{1}{2} \) its weight of water, after which another third to one-half of brown sulphuric acid is added. The pasty mass is allowed to cool, in the mixing vessel, or when large quantities are prepared, the semi-liquid mass in the mixer is run out still hot, fresh quantities of bone-dust, water, and acid are put in the mixer, and after 5 or 10 minutes the contents allowed to run out, and a fresh quantity prepared as before. The successive mixings are all kept together in one heap for 1 or 2 months; the heap is then turned over and, if necessary, the partially dissolved bones are passed through a riddle.

In a similar manner, coprolites, bone-ash, apatite and other phosphate minerals are treated with acid. It ought to be observed, however, that the quantity of brown sulphuric acid necessary for dissolving coprolites must be at least \( \frac{1}{2} \) of the weight of coprolite powder, for coprolites contain much carbonate of lime, which neutralizes sulphuric acid. Even 75 per cent. of brown acid are not always sufficient to dissolve completely coprolite powder, and as the proportion of carbonate of lime in coprolites and sulphuric minerals varies considerably, it cannot be stated definitely what amount of oil of vitriol should be used in every case.

The safest plan, therefore, for the manufacturer is, to ascertain from time to time whether the proportion of acid which he has used has converted nearly the whole of the
insoluble phosphates in coprolites into soluble phosphates, and if necessary to add more acid. In the case of bone-dust, it does not matter if the whole of the bone-earth is not rendered soluble; bones even partially acted upon by oil of vitriol, become sufficiently soluble in the soil to prove efficacious for the turnip crop. But the case is different, if mineral phosphates, such as apatite or coprolite powder, are employed in the manufacture of superphosphate. Insoluble phosphates in the shape of coprolite powder are not worth any thing in an artificial manure, for they are too insoluble to be taken up by the turnip crop. It is therefore essential to employ a quantity of acid, which is amply sufficient to convert the whole of the insoluble phosphate of lime in coprolites into soluble, as biphosphate of lime. See COPROLITES.—A. V.

MELAMINE. C7H10N2. An alkali produced from melam under the influence of boiling potash. It is isomeric with cyanamide, from which it may be produced by the action of heat.—G. W.

MERCURY or QUICKSILVER. Mr. Russell Bartlett, the United States Commissioner on the Mexican and United States Boundary Question, who visited California in 1853, states that the quantity of quicksilver produced annually at New Almaden, exceeds 1,000,000 lbs. During the year 1853 the total exports from San Francisco amounted to 1,550,000 lbs. valued at 683,189 dollars. All this, together with the large amount used in California, was the produce of the New Almaden mine in the Santa Clara county, 12 miles from the town of San Jose, which is 54 miles from the city of San Francisco. The working of the mine was begun in the year 1846-7, by an English company, but for some reasons was not profitable. In 1849-50 it fell into American hands. The following shows what points of the following more recently traded in 1855:—Hong Kong, 425,150 lbs.; Shanghai, 60,900 lbs.; Canton, 37,150 lbs.; Whampoa, 22,500 lbs.; Calcutta, 3,750 lbs.; Mazatlan, 210,825 lbs.; Mazatlan and San Blas, 19,125 lbs.; San Blas, 145,652 lbs.; Callao, 135,000 lbs.; Valparaiso, 148,275 lbs.; New York, 138,375 lbs.; Philadelphia, 75,000 lbs. The ore is cin- nabar of a bright vermilion color. Its specific gravity is 5,622.

The portion of the fluid metal is extracted is one of great simplicity. There are 6 furnaces, near which the ore is deposited from the mine, and separated according to its quality; the larger masses are first broken up, and then all is piled up under sheds near the furnace doors. The ore is next heaped on the furnaces, and a steady though not a strong fire is applied; as the ore becomes heated the quicksilver is sublimed, and being condensed it falls by its own weight, and is conducted by pipes which lead along the bottom of the furnace to small pots or reservoirs imbedded in the earth, each containing from 1 to 2 gallons of the metal. The furnaces are kept going night and day, while large drops or minute streams of the pure metal are constantly trickling down into the receivers; from these it is carried to the storehouse and deposited in large cast-iron tanks or vats, the largest of which is capable of containing 20 tons of quicksilver. Seven or eight days are required to fill the furnaces, extract the quicksilver, and remove the residuum. The miners and those who man the chimneys are thereby exposed to serious injury; but the work about the furnaces and inhale the fumes of the metal are seriously affected. Salivation is common, and the attendants on the furnaces are compelled to desist from their labor every 3 or 4 weeks, when a fresh set of hands is put on. The horses and mules are also salivated, and from 20 to 30 of them die every year from the effects of the mercury.

The following more detailed account of the apparatus for melting is given by Mr. Ruschenberger:—A kind of reverberatory furnace 3 feet by 5 is arranged at the extremity of a series of chambers, of nearly, if not exactly of the same dimensions, namely, 7 feet long, 4 wide, and 5 high. There are 8 or 10 of these chambers in each series; they are built of brick, plastered inside, and secured by iron rods, armed at the end with screws and nuts as a protection against the expansion by heat. The tops are of boiler iron luted with ashes and salt. The first chamber is for a wood fire. The second is the ore chamber, which is separated from the first by a net-work partition of brick. The flame of the fire passes through the square holes of this partition, and plays upon the ore in the ore chamber, which when fully charged contains 10,000 lbs. of cinnambar; next to the ore chamber is the first condensing chamber, which communicates with it by a square hole at the right upper corner; and the communication of this first with the second condensing chamber is by a square hole at the left lower corner. An opening at the right upper corner of the partition, between the second and third condensing chamber, communicates with the latter. The openings between the chambers are at the top, and to the right, and at the bottom, and to the left alternately; so that the vapors from the ore chamber are forced to describe a spirall in their passage through the 8 condensers. The vapors and smoke pass from the last condensing chamber through a square wooden box, 8 or 10 feet long, in which there is a case: inimous shower of cold water, and finally escape into the open air by tall wooden flues. The floor or bottom of each condensing chamber is about 2 feet above the ground, and is arranged with gutters for collecting the condensed mercury and conveying it out into an open conduit, along which it flows into an iron receptacle, from which it is poured into the iron flasks through a brush to cleanse it of the scum of oxide formed on the surface on
standing. 70 lbs. weight are poured into each flask. There are 14 of these furnaces and ranges of condensers, with passages of 8 or 10 feet in width between them. A shed is constructed above the whole at a sufficient elevation to permit free circulation of the air.

According to Dunne, the following mines yield annually as follows:—Almaden in Spain, from 2,700,000 to 3,456,000 lbs. avoirdupois; Idrin, 648,000 to 1,080,000 lbs.; Hungary and Transylvania, 75,600 to 97,200; Deux Points, 43,000 to 54,000 lbs.; Palatinate, 19,440 to 21,600 lbs.; Hunanvedica, 324,000 lbs.

METALLOGRAPHY. A process invented by M. Abate, and published by him in 1881. It consists of printing from engraved wood-blocks upon metallic surfaces, so as to produce imitations of figures and ornaments inlaid in wood. This effect is obtained by using, as a printing menstruum to wet the block with, solutions of such metallic or earthy salts as are decomposed when brought into contact with certain metals, and produce, through an electro-chemical action, an adhesive precipitate of a colored metallic oxide, or any other chemical change upon the metal. There are here two principles at work: one is the chemical action just referred to; the other—the formation and key-stone to the invention—rests in the porosity of the printing object, which causes the absorption of the wetting fluid. The application of the invention to printing upon vegetable substances instead of metallic surfaces, required the introduction into the process of some other principle, to produce that chemical change which in metallography is spontaneous. The following is M. Abate's description of his process:

Suppose a sheet of veneering wood to be the object from which impressions are to be taken; the wood is exposed for a few minutes to the cold evaporation of hydrochloric or sulfuric acid, or is slightly wetted with either of those acids diluted, and the acid is wiped off from the surface. Afterwards it is laid upon a piece of calico, or paper, or common wood, and by a stroke of the press an impression is taken, but which is quite invisible; now by exposing this impression immediately to the action of a strong heat, a most perfect and beautiful representation of the printing wood instantaneously appears. In the same way, with the same plate of wood, without any other acid preparation, a number of impressions, about twenty or more, are taken; then, as the acid begins to be exhausted and the impressions faint, the acidification of the plate must be repeated as above, and so on progressively, as the wood is not in the least injured by the working of the process for any number of impressions. All these impressions show a most natural for the light-colored woods, such as oak, walnut, maple, &c., but for other woods that have a peculiar color, such as mahogany, rosewood, &c., the impression must be taken, if a true imitation be required, on a stuff dyed with the right color of the wood.

It must be remarked, that the impressions as above made show an inversion of tints in reference to the original wood, so that the light are dark, and vice versa, which, however, does not interfere with the effect. The reason of it is, that all the varieties of tints which appear in the same wood are the effect of the varying closeness of its fibres in its different parts, so that where the fibres are close the color is dark, and light where they are loose; but in the above process, as the absorption of the acid is greater in proportion to the looseness of its fibres, the effect must necessarily be the reverse of the above. However, when it is required to produce the true effect of the printing wood, the process is altered as follows:—The surface upon which the impression is to be taken is wetted with dilute acid, and an impression is taken with the veneering-wood previously wetted with diluted ammonia; it is evident that in this case, the alkali neutralizing the acid, the effect resulting from the subsequent action of heat will be a true representation of the printing surface. M. Abate gives this variation of the process the name of THERMOGRAPHY, or the art of printing by heat; but this term has been already applied to another process.

METALLURY. (Erzevkunde, Germ.) The art of extracting metals from their ores. Under the heads of the different metals respectively, the metallurgical processes to which they are subjected are given; still there are a few general details, which are included with advantage in the present article. A full description of the processes of preparing the minerals for the operations of the metallurgist will be found under the head of ORES, DRESSING OR.

Most of the tin ores in Cornwall have to be roasted, or calcined, before they are fit for the smelting-house, although in some mines the admixture with other minerals is so trifling, that this operation is considered unnecessary. The furnace (figs. 420, 421) in which the roasting is carried on, is about 10 feet long, 5 feet 6 inches wide in the middle, and 3 feet wide near the mouth. The fireplace, it will be observed, is situated at the back, the flames playing through the oven and ascending the chimney, which is above the furnace door. The man is represented in fig. 421 as stirring the ore with a long iron rake. The ore, before it is submitted to the action of the fire, is thoroughly dried in a circular pit, placed immediately above the oven, into which it is let down through the opening when it is considered to be ready for calcining. Beneath the oven and connected with it by an opening through which the ore when sufficiently roasted is made to pass, is an arched opening about 4 feet wide, termed the "wrinkle." Here the ore is collected, whilst another charge is being placed in the furnace. About 7 cwt. or 8 cwt. of ore is the quantity usually roasted at one
time. Whilst undergoing this operation, dense fumes of arsenic and sulphur escape with the smoke from the fire, and pass through large flues, divided into several chambers, (fig. 420.

422.) where the former is collected. The flue is often 70 yards long, and the greatest deposit of arsenic takes place at about 15 yards from the oven or furnace. Instead of being

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at once completely roasted, the "whites" from the stamps are sometimes first "rag" (or partially) burnt, for about six or eight hours. The object of this partial burning is to save
time and expense, nearly three-fourths of it being thrown away after dressing it from the first burning.

Fig. 423. The machine called originally "Brunton's Patent Calciner," for calcining tin ore, is gradually coming into use in Cornwall, and is adopted in many of the larger mines. Its operation may be thus briefly described:—A revolving circular table, usually 8 feet, or 10 feet in diameter, turned by a water-wheel, receives through the hopper the tin stuff to be roasted or calcined. The frame of the table is made of cast-iron, with bands, or rings, of wrought iron, on which rests the fire-bricks composing the surface of the table. The flames from each of the two fireplaces pass over the ore as it lies on the table, which slowly revolves, at the rate of about once in every quarter of an hour. In the top of the dome, over the table, are fixed three cast-iron frames called the "spider," from which depend numerous iron coulter, or teeth, which stir up the tin stuff, as it is carried round under them. The coulter on one of the arms of the "spider" are fixed obliquely, so as to turn the ore downwards from one to the other—the last one at the circumference of the table, projecting the ore (by this time fully calcined) over the edge, into one of the two "wrinkles" beneath. A simple apparatus called the "butterfly," moved by a handle outside the building, diverts the stream of roasted tin stuff, as it falls from the table, either into one or the other,
as may be required. Unlike the operation of roasting in the oven previously described, the calci
er requires little or no attention; the only care requisite being to see that the hopper
is fully supplied, and the roasted ore removed when necessary from the wrinkles.

For this description of the burning-house and of the calci
er, we are indebted to Mr. James Henderson's communication to the Institution of Civil Engineers.

We have been favored with the following notes on the action of Brunton's calci
ers, employed at Fabrta la Constanta, Spain, which are of great value, as are also the additional
suggestions:

- Diameter of revolving bed, 14 feet.
- Revolution of bed per hour from 3 to 4, or about 1 foot of the circumference per minute.
- Gas introduced by hopper, at the rate of 1 quintal to every revolution of table.
- Quantity of ore calcined per day of 10 hours, 30 to 35 quintals.
- Salt consumed, generally 6 per cent. of weight of ore.
- Fuel consumed per 10 hours, 1,200 to 1,400 lbs. of pine wood.
- Power employed to revolve table, half horse.

Remarks.—The furnace is charged with ore and salt by means of iron hoppers placed
immediately over the centre of each of the hearths. For the supply of each hopper, a
heap of about 14 quintals of ore, with 5 or 6 per cent. of salt, is prepared from time to
time upon a small platform on the top of the furnaces, and a few shovelfuls thrown in occa
sionally as required, taking care, however, always to have enough ore in the hopper to pre
vent the ascension of acid vapors, &c., from the furnace. The time the mineral remains in
the furnace, and the quantity calcined per hour, must depend on the rapidity of motion of
the revolving hearth, and the angle at which the iron stirrers are fixed.

The average amount passed through each furnace in 24 hours is about 84 quintals, or
3½ quintals per hour. For every revolution of the bed, nearly 1 quintal is discharged from
the furnace.

Compared with the German Röstöfen, the mechanical furnaces are less efficient for the
calcination of silver ores, particularly when the ores operated on are very damp, and contain
much sulphur; in which case the excessive production of lamps becomes a serious in
convenience to contend with.

But in the treatment of the silver ores of Steindelencira, they possess the advantage of
calcining a large quantity of ore in a given time, and require no further attendance than is
necessary for supplying them with ore and fuel. The supply of fuel is, however, subject to
great neglect. The management of the fires is nevertheless a matter of much importance,
for should they be forgotten, and the heat get much reduced, the mineral, from continuing
to pass at the same rate through the furnace, cannot be properly calcined.

To prevent the fires getting low, and to raise them after being neglected, the workmen
often load the grate with fuel, the result of which is to overheat the ore and cause a great
waste of wood.

Some measure is evidently necessary to regulate the supply of fuel to the grate.
The most simple appears to be an alurnum that shall be rung, for example, at every revolu
tion of the hearth, so as to call the attention of the men to the fires; and then not more than
a given quantity of wood should be thrown on the grate, which, repeated at every
turn made by the bed, or once in a quarter of an hour, would sustain a nearly constant tem
perature in the furnace. See Silver.

METER, GAS. The most recently constructed meters on the dry principle are those
of Defries, and of Messrs. Croll & Richards. Both of these contrivances consist in causing
the gas to fill expandable chambers of definite volume, and the alternate expansion and con
traction of these is registered by wheel-work.

Defries' meter has three of these measuring chambers, separated from each other by
flexible leather partitions which are partly covered by metallic plates, to protect them from
the action of the gas. A A A A, (fig. 424,) represent these metallic plates fixed upon the
leather diaphragm. B B B. As the gas enters, it causes the flexible partition to expand,
which it does by assuming the form of a cone, as seen in fig. 425. Three such chambers
are attached to each meter, so as to insure a uniform and steady supply of gas, and the
motion of the chambers being communicated to clockwork, the consumption of gas is regis
tered upon dials in the usual manner.

The dry meter invented by Messrs. Croll & Richards is superior in construction and
accuracy of measurement to that of Defries. It is shown in figs. 426, 427, and 428. A A,
(fig. 426, is a cylindrical case divided into two cylindrical compartments by the inflexi
ble metallic diaphragm n. These compartments are closed at opposite ends by the metal discs
A A. The latter perform the functions of pistons, and are retained in their proper position
by universal joints attached to each. The discs are restrained from moving through more
than a fixed space by metallic arms and rods, shown in fig. 427, and when this space has
been once adjusted it cannot afterwards vary. It will be seen that the principle of this
meter is that of a piston moving in a cylinder; but, in order to avoid the friction which
such an arrangement would cause if literally carried out, bands of leather, p d, are attached, which act as hinges, and allow of the motion of the discs without friction.

The gas enters the cylinder from the upper space containing the levers, valves, &c., (fig. 428;) its pressure forces the discs forward through the space limited, as above described.
METRA. 749

The flow of gas is then reversed; that is, a passage to the burners is opened from the internal space, whilst the supply is now directed into the outer chamber, thus forcing the disc back to its original position and expelling the first portion of gas through the pipes of distribution. Each motion of the disc thus evidently corresponds to a given volume of gas, and, being registered by clockwork, indicates the consumption upon the usual dial plates.

Dry gas-meters have of late years come into very extensive use, especially in the metropolis.—E. F.

METRA. This pocket instrument, constructed by the late Mr. Herbert Mackworth—one of H. M. Inspectors of Collieries,—enables the traveller or engineer to take, with considerable accuracy, most of those measurements which it is useful to record, and to make use of opportunities which would otherwise be lost. In a brass case, less than three inches square and an inch thick, are contained a clinometer, thermometer, goniometer, level, magnifying lens, measure for wire gauze, plummet, platinum scales of various kinds, and an anemometer. The traveller can ascertain by its means the temperature, the force of the wind, the latitude, the position of the rocks, or survey and map his route. The geologist can determine and draw the direction and amount of dip of the rocks, the angles of cleavage and crystallization, the temperature of springs, or examine by a plate of tourmaline the bottoms of pools or shallow depths along coast lines otherwise invisible to the eye. The miner can survey and level the roof or floor of his workings, and requires only a pencil to map them upon paper. He can ascertain the temperature of the air under ground, discover whether the ventilation is deficient, or see whether the wires of his Davy lamp are in safe condition. Figs. 429, 430 represent the plan and side view of the "metra" when open and ready for use. A is the double compass, and B the level. The arc of the level is graduated in

degrees, and in inches fall per yard. C the sights; D the scales; E the goniometer; F the goniometer scale; G the plummet; H the lens, with a telescopic slide underneath to measure wire gauze; I the tourmaline; J the pivots on which the instrument stands; K are the two joints of the brass leg, by which the horizontality of the instrument can be obtained;
MINERAL CANDLES. These candles and other products (liquid hydro-carbons) are manufactured by Price's Candle Company, at Belmont and Sherwood, according to processes patented by Mr. Warren De la Rue. The novelty of these substances consists in their being obtained 1. in the method of operation by which the are obtained. 2. in the method by which they are elaborated. 3. in their chemical constitution.

The raw material is a semi-fluid naphtha, drawn up from wells sunk in the neighborhood of the river Irrawaddy, in the Burmese empire. The geological characteristics of the locality are sandstone and blue clay. In its raw condition the substance is used as a preservative of timber against insectitis. It is not, however, part volatile at common temperatures, this naphtha is imported in hermetically closed metallic tanks, to prevent the loss of any constituent. Reichenhau, Christison, Gregory, Reece, Young, Wiesman, (of Bonn,) and others, have obtained it from peat, coal, and other organic materials, solids and liquids bearing some physical resemblance to those procured from the Burmese naphtha; but the first-named process has, in every instance, been formed by the decomposition of the raw material. The process of De la Rue is, from first to last, a simple separation, without chemical change.

In the commercial processes, as carried out at the Sherwood and Belmont Works, the crude naphtha is first distilled with steam at a temperature of 212° F.; about one-fourth is separated by this operation. The distillate consists of a mixture of many volatile hydrocarbons; and it is extremely difficult to separate them from each other on account of their vapors being mutually very similar. However, they may be separated by their boiling points. In practice, recourse is had to a second or third distillation, the products of which are classified according to their boiling points or their specific gravities, which range from .27 to .60, the lightest coming over first. It is worthy of notice, that though all these volatile liquids were distilled from the original material with steam of the temperature of boiling water, their boiling points range from 80° F. to upwards of 400° Fahr.

These liquids are all colorless, and do not solidify at any temperature, however low, to which they have been exposed. They are useful for many purposes. All are solvents of caoutchouc. The vapor of the more volatile Dr. Snow has found to be highly anesthetic. Those which are of lower specific gravity are called in commerce Sherwoodolde and Belmonotine; these have great detergent power, really removing oily stains from silk, without impairing even delicate colors. The distillate of the higher specific gravity is proposed to be used as lamp-fuel; it burns with a brilliant white flame, and, as it cannot be ignited without a wick, even when heated to the temperature of boiling water, it is safe for domestic use.

A small percentage of hydro-carbons, of the benzole series, comes over with the distillates in this first operation. Messrs. De la Rue and Müller have shown that it may be advantageously eliminated by nitric acid. The resulting substances, nitro-benzole, &c., are commercially valuable in perfumery, &c.

After steam of 212° has been used in the distillation just described, there is left a residue, amounting to about three-fourths of the original material. It is fused and purified from extraneous ingredients (which Warren De la Rue and H. Müller have found to consist partly of the olephane series) by sulphuric acid. The foreign substances are thus thrown down as a black precipitate, from which the supernatant liquor is decanted. The black precipitate, when freed from acid by copious washing, has all the characteristic properties of native asphaltum. The fluid is then transferred to a still, and, by means of a current of steam made to pass through heated iron tubes, is distilled at any required temperature. The distillates obtained by this process are classed according to their distilling points, ranging from 500° to 600° Fahr. The distillations obtained, at 450° Fahr. and upwards, con-
tain a solid substance, resembling in color and in many physical and chemical properties the paraffine of Reichenbach; like it, it is electric, and its chemical affinity is very feeble; but there are reasons for believing that a difference exists in the atomic constitution of the two substances. The commercial name of Belmonetine is given to one of the fluids from the Burmese pitch. Candles manufactured from the solid material (Paraffine) possess great illuminating power. It is stated that such a candle, weighing 1/2 lb, will give as much light as a candle weighing 4 lb, made of spermaceti or of stearic acid. Its property of fusing at a very low temperature into a transparent liquid, and not decomposing below 60° Fahr., recommends this substance as the material of a bath for chemical purposes. As to the fluids obtained in the second distillation, already described, they all possess great lubricating properties; and, unlike the common fixed oils, not being decomposable into an acid, they do not corrode the metals, especially the alloys of copper, which are used as bearings of machinery. This aversion to chemical combination, which characterizes all these substances, affords not only a security against the brass-work of lamps being injured by the hydro-carbon burnt in them, but also renders these hydro-carbons the best detergents of common oil lamps. It is an interesting physical fact, that some of the non-volatile liquid hydro-carbons possess the fluorescent property which Stokes has found to reside in certain vegetable infusions.

An important characteristic of the Burmese naphtha is its being almost entirely destitute of the hydro-carbons belonging to the olefiant gas series. See Naphtha.

Mines of North America. Within the last few years a stupendous activity in the production of certain metals has succeeded to the unimportant trials which at intervals used to be made in the earlier part of this century. It is especially the discovery of gold in California in 1848, which has invited the attention of the world to the metallic riches of the Pacific side of this continent, or to the western flank of the continuation of the great chain of mountains which we have traced upwards from South America.

Almost the entire quantity of the gold produced in California is obtained from streams, washings, or "diggings," but the precious metal itself has evidently been derived from the pyramids and the ancient slaty rocks which constitute the range of the Sierra Nevada. Numerous veins, consisting principally of quartz, have been proved to be auriferous, but although large companies, mostly English, have been organized for working them, little success has yet attended their efforts. Platinum and osmiridium have also been found here, thus establishing an analogy with the Brazilian localities.

The auriferous tract extends northward far into the British territory. In one of the side valleys of San José, a mine of quicksilver, "New Almaden," has for some years been opened upon irregular and contorted deposits of cinnebar, associated with clay slates highly inclined and similarly contorted. It is said that above 10,000 cwt. of mercury are produced here annually.

On the eastern or Atlantic side of the North American continent, the existence of gold has long been known, as well in alluvium in Virginia, Carolina, Georgia, and Canada, as in veins which occur at intervals in the schist rocks of the Appalachian chain, and which have given rise to numerous explorations.

The veins appear generally to course N.N.E. and S.S.W. and to consist mainly of quartz, often extending to a great thickness. Few, however, of these mines have been followed down to a depth of more than 100 feet, or have been developed on a continuously large scale.

Lead mines have been worked in distinct veins at Rossie, St. Lawrence County, N. Y., at Shilburne in New Hampshire, Southampton and Northampton, in Massachusetts, Middletown, Connecticut, Chester County, and Wheatley mines, Pennsylvania; but the most important are those opened in irregular deposits sometimes vertical, at others horizontal, which distinguish the Silurian limestones of the Upper Mississippi. The lead-bearing region is 87 miles long from east to west, and 24 miles broad from north to south, the chief centres being Galena, Mineral Point, and Dubuque. The ore, generally pure galena, occurs with great irregularity, and thus leads to the expenditure of large sums in "prospecting" of a very speculative character. It occupies only one zone, about 100 feet in thickness, of the "galena" limestone, and hence the mines have been but shallow, and the production is on the decline, having dwindled from 24,400 tons of lead in 1845, to 13,300 in 1853. In Missouri an analogous state of things occurs, but on a smaller scale. Copper has been worked at several mines in the Atlantic States, at Bristol, Connecticut; Sykesville, &c., in Maryland; Schuyler, and other mines, New Jersey; several newly opened localities in Tennessee; and Perkiomen in Pennsylvania, where the veins occur in new red sandstone and shale.

In 1841 the publication of Mr. Doughton, State geologist for Michigan, first drew public attention to the native copper of Lake Superior, which since 1844 has been the object of very numerous workings, and has been produced in steadily increasing quantity up to 5,000 tons per annum.

The veins here occur in a district of bedded augite greenstone, amygdaloid, and sand-
stone, with conglomerate of the lower Silurian period, and are especially remarkable for bearing native copper without any of the ordinary ores of that metal.

Ores of zinc are associated with lead ores at several of the above-mentioned localities, especially in the Wisconsin district, where the calamine is known among the miners by the name of "dry-bone." But one of the most peculiar mineral deposits in the United States is that of the red oxide of zinc, and of Franklinite, which occur in Sussex, New Jersey, at Sparta and Stirling. They are intercalated among the beds of a crystalline limestone, with a total thickness of above 30 feet, and are the scene of very successful undertakings.

Lastly, iron ores of various species, particularly the magnetic oxide and hematite, occur in numerous localities. Missouri is remarkable for large masses which are said to have an eruptive character, and Lake Superior offers even a greater abundance.

A bed of black oxide of iron occurs in gneiss near Franconia in New Hampshire. It has a width of from 5 to 8 feet; and has been mined through a length of 200 feet, and to a depth of 90 feet. The same ore is found in veins in Massachusetts and Vermont, accompanied by copper and iron pyrites. It is met with in immense quantities on the western bank of Lake Champlain, forming beds of from 1 to 20 feet in thickness, almost without mixture, encased in granite. It is also found in the mountains of that territory. These deposits appear to extend without interruption from Canada to the neighborhood of New York, where an exploration on them may be seen at Crown-Point. The ore there extracted is in much esteem. Several mines of the same species exist in New Jersey. The primary mountains which rise in the north of this State near the Delaware, include beds almost vertical of black oxide of iron, which have been worked to 100 feet in depth. In the county of Sussex the same ore occurs, accompanied with Franklinite. At Roxbury, in Connecticut, a good sized lode of sparry iron occurs; the only one of the kind known in the Alleghanies. The United States contain a great many iron works, some of which prior to the year 1773 sent over iron to London. Those in Connecticut, Massachusetts, and New York, have been largely supplied with iron ores of the tertiary formation, whilst those of Virginia and Maryland employ on an extensive scale coal measure ironstone.

Before quitting America, it should be mentioned that the West India Islands offer numerous indications of minerals. Many cupriferous veins have been explored on a small scale in Jamaica. Copper ore and molybdenite occur at Virgin Gorda, and Cuba has for many years past been remarkable for the richness and abundance of its copper ores. The principal mine is the Oreba, an adventure worked on an extensive scale, and very remunerative to its proprietor. The lodes, which have been very large at shallow depths, course E. and W. through greenstone and conglomerite rock. The Santiago mines have also yielded a large amount of ore.

MINING. As the operations of mining vary with the conditions of the rock formations, in which the minerals sought for by the miner occur, it is necessary to give a brief description of the more especially marked distinctions which are seen in our geological formations.

Geologist divide rocks into stratified and unstratified. Those mineral systems which consist of parallel, or nearly parallel planes, whose length and breadth greatly exceed their thickness, are called stratified rocks; while those which occur in thick blocks, and which do not exhibit these parallel planes, the term of unstratified rocks is applied. These formations have been divided into two other classes, namely the primary and the secondary. The advances of geological science, however, and more accurate information, have materially modified the views which gave rise to those divisions; and when men have learned to look on great natural phenomena without the interposition of the medium of some favorite theory, there is but little doubt the interpretation will be somewhat different from even that which is now received.

A certain set of rocks may be classed as of truly igneous origin. These are the traps, basalts, and the like. These have often been termed primary rocks. Yet we have rocks of this class, not merely forcing their way through the superincumbent and more recent rocks, but actually overflowing them: they may, therefore, be much more recent than the secondary rocks. Granite has commonly been classed as a truly igneous rock; but facts have lately been developed which show, at all events, the combined action of water, and the probability appears to be that granite, gneiss, and elvan have been formed under highly heated water.

Granite is usually classed with the unstratified rocks; but the section of any granite quarry will exhibit very distinct lines, conforming, more or less, to the horizontal—known to the quarrymen as the bedway—which would appear sufficient to place these rocks amongst the stratified ones.

It is commonly stated that the unstratified rocks possess a nearly vertical position, the stratified rocks assuming more nearly a horizontal one. There are numerous examples adverse to this view; indeed, it must be regarded as a hasty generalization—the bedway of the granite approaching very nearly to the horizontal, while we often find the truly stratified rocks in a vertical position.
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Where the older rocks graduate down into the plains, rocks of an intermediate character appear, which, though possessing a nearly vertical position, like the stratified and non-fossiliferous rocks, contain a few vestiges of animal beings, especially shells. These have been called transition, to indicate their being the passing links between the first and second systems of ancient deposits; they are distinguished by the fractured and cemented texture of their planes, for which reason they are sometimes called conglomerate.

Between the older and the secondary rocks, another very valuable series is interposed in certain districts of the globe; namely, the coal-measures, the paramount formation of Great Britain. The coal strata are frequently disposed in a basin-form, and alternate with parallel beds of sandstone, slate-clay, iron-stone, and occasionally of limestone.

As a practical rule it may be here stated, that in every mineral formation, the inclination and direction are to be noted; the former being the angle which it forms with the horizon, the latter the point of the azimuth or horizon, towards which it dips, as west, northeast, south, &c. The direction of a bed is that of a horizontal line drawn in its plane; and which is also denoted by the point of the compass. Since the lines of direction and inclination are at right angles to each other, the first may always be inferred from the second; for when a stratum is said to dip to the east or west, this implies that its direction is north and south.

The following terms have been used to express dissimilar conditions in mineral deposits, well known to the practical miner.

**Masses** are mineral deposits, not extensively spread in parallel planes, but irregular heaps, rounded, oval, or angular, enveloped in whole or in a great measure by rocks of a different kind. Lenticular masses being frequently placed between two horizontal or inclined strata, have been sometimes supposed to be stratiform themselves, and have been accordingly denominated by the Germans liegende stecke, lying heaps or blocks.

The orbicular masses often occur in the interior of unstratified mountains, or in the bosom of one bed. These frequently indicate preexisting cavernous spaces, which have been filled in with metalliciferous or mineral matter.

**Nests, concretiones, nodules,** are small masses found in the middle of strata; the first being commonly in a friable state; the second often kidney-shaped, or tuberous; the third nearly round, and eneurusted, like the kernel of an almond.

**Lodes, or veins,** are flattened masses, with their opposite surfaces not always parallel. These sometimes terminate like a wedge, at a greater or less distance, and do not run parallel with the rocky strata in which they lie, but cross them in a direction not far from the perpendicular; often traversing several different mineral planes. The lodes are sometimes deranged in their course, so as to pursue for a little way the space between two contiguous strata; at other times they divide into several branches. The matter which fills the lodes is for the most part entirely different from the rocks they pass through, or at least it possesses peculiar features.

This mode of occurrence suggests the idea of clefts or rents having been made in the stratum posterior to its consolidation, and of the vacuities having been filled with foreign matter, either immediately or after a certain interval. There can be no doubt as to the justice of the first part of the proposition, for there may be observed round many lodes undeniable proofs of the movement or dissolution of the rock; for example, upon each side of the rent the same strata are no longer situated in the same plane as before, but make greater or smaller angles with it; or the stratum upon one side of the lode is raised considerably above, or depressed considerably below, its counterpart upon the other side. With regard to the manner in which the rent has been filled, different opinions may be entertained. In the lodes which are widest near the surface of the ground, and graduate into a thin wedge below, the foreign matter would seem to have been introduced as into a funnel at the top, and to have carried along with it portions of rounded gravel and sometimes, though rarely, organic remains. In other, but very exceptional cases, lodes are largest at their under part, and become progressively narrower as they approach the surface; from this circumstance, it has been inferred that the rent has been caused by an expansive force acting from within the earth, and that the foreign matter, having been in a fluid state, has afterwards slowly crystallized. Accurate observation shows that in the large majority of cases the metalliciferous deposits are of aequous, and not of igneous origin.

In the lodes, the principal matters which fill them are to be distinguished from the accessory substances; the latter being distributed irregularly, amidst the mass of the first, in crystals, nodules, grains, seams, &c. The non-metalliciferous portion, which is often the largest, is called gangue, from the German gang, vein. The position of a vein is denoted, like that of the stratum, by the angle of inclination, and the point of the horizon towards which it dips, whereon the direction is deduced. In popular language a lode may be described to be a crack or fissure, such as is formed in the drying of a pasty mass, extending over a considerable extent of country, and penetrating to a great depth into the earth.

A metalliciferous substance is said to be disseminated, when it is dispersed in crystals, spangles, scales, globules, &c., through a large mineral mass. Tin is not unfrequently thus disseminated through granite and clay-slate rocks.

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Certain ores which contain the metals most indispensable to human necessities, have been treasured up by the Creator in very bountiful deposits; constituting either great masses in rocks of different kinds, or distributed in lodes, veins, nests, concretions, or beds, with stony and earthy admixtures; the whole of which become the objects of mineral exploration. These stores occur in different stages of the geological formations; but their main portion, after having existed abundantly in the several orders of the older strata, cease to be found towards the middle of the secondary rocks. Iron ores are, with a few exceptional cases, the only ones which continue among the more modern deposits, even so high as the beds immediately beneath the chalk, when they exist almost entirely as coloring matters of the tertiary beds.

Granite, gneiss, mica, and clay-slate constitute in Europe the grand metallic domain. There is hardly any kind of one which does not occur in these in sufficient abundance to become the object of mining operations, and many are found in no other rocks. The transition rocks and the lower part of the secondary ones, are not so rich, neither do they contain the same variety of ores. But this order of things, which is presented by Great Britain, Germany, France, Sweden, and Norway, is far from forming a general law; since in equinoctial America the gneiss is but little metalliferous; while the superior strata, such as the clay-ochrists, the sillurian perphyries, the limestones, which complete the transition series, as also several secondary deposits, include the greater portion of the immense mineral wealth of that region of the globe.

All the substances of which the ordinary metals form the basis, are not equally abundant in nature; a great proportion of the numerous mineral species which figure in our classifications, are more varieties scattered up and down in the cavities of the great masses or lodes. The workable ores are few in number, being mostly sulphides, oxides, and carbonates. These occasionally form of themselves very large masses, but more frequently they are blended with lumps of quartz, felspar, and carbonate of lime, which form the main body of the deposit. The ores in that case are arranged in small layers parallel to the strata, or in small veins which traverse the rock in all directions, or in nests, or concretions stationed irregularly, or finally disseminated in hardly visible particles. These deposits sometimes contain only one species of ore, sometimes several, which must be mixed together, as they seem to be of contemporaneous formation: whilst, in other cases, they are separable, having been probably formed at different epochs.

**Mineral Veins.**—In different districts in this country the terms used to distinguish mineral veins vary considerably. The following terms prevail in Derbyshire and the north of England:

Lodes or mineral veins are usually distinguished by the miners of these districts into at least four species:—1. The rake vein. 2. The pipe vein. 3. The flat or dilated vein; and 4. The interlaced mass, (stockwerk,) indicating the union of a multitude of small veins mixed in every possible direction with each other, and with the rock.

1. The rake vein is a mineral fissure, and is the form best known among practical miners. It commonly runs in a straight line, beginning at the superficies of the strata, and cutting them downwards, generally further than can be reached. This vein sometimes stands quite perpendicular; but it more usually inclines or hangs over at a greater or smaller angle, or slope, which is called by the miners the **hade** or **heading** of the vein. The line of direction in which the fissure runs, is called the **bearing** of the vein.

2. The pipe vein resembles in many respects a huge irregular cavern, pushing forward into the body of the earth in a sloping direction, under various inclinations, from an angle of a few degrees to the horizon, to a dip of 45°, or more. The pipe does not in general cut the strata across like the rake vein, but insinuates itself between them; so that if the plane of the strata be nearly horizontal, the bearing of the pipe vein will be conformable; but if the strata stand up at a high angle, the pipe shoots down nearly headlong like a shaft. Some pipes are very wide and high, others are very low and narrow, sometimes not larger than a common mine or drift.

3. The flat or dilated vein, is a space or opening between two strata or beds of stone, the one of which lies above, and the other below this vein, like a stratum of coal between its roof and pavement: so that the vein and strata are placed in the same plane of inclination. These veins are subject, like coal, to be interrupted, broken, and thrown up or down by slips, dykes, or other interruptions of the regular strata. In the case of a metallic vein, a slip often increases the chance of finding more treasure. Such veins do not preserve the parallelism of their beds, characteristic of coal seams, but vary excessively in thickness within a moderate space. Flat veins occur frequently in limestone, either in a horizontal or declining direction. The flat or strata veins open and close, as the rake veins also do.

4. The interlaced mass has been already defined. The interlaced strings are more frequent in primitive formations, than in the others.

To these may be added the accumulated vein, or irregular mass, (Unterwerke,) a great deposit placed without any order in the bosom of the rocks, apparently filling up cavernous spaces.
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In Cornwall and Devonshire, where different conditions prevail, other terms are employed.

The lode, or mineral vein, is, as in the former instances, a great line of dislocation, accompanied by minor lines of fracture. Of these Sir H. De la Beche says: "It could scarcely be supposed that the great lines of fracture would be accompanied by smaller dislocations, running from them in various directions according to modifying resistances, which would depend upon the kinds of rock traversed by the great fractures, the direction in which they were carried through them as regards the bearing of their strata, should they be stratified, and other obvious causes. The great fractures would often also tend to split in various directions and reunite into main lines, as in the annexed sketch, (fig. 451,) in which a b represents the line of principal fracture, splitting at b b from local causes, and uniting, both towards a and b, minor cracks running into the adjoining rock at c, c, c, c. These are known as side lodes, strings, feeders, and branches.

These strings are sometimes very curiously developed, and illustrate the peculiar force of crystalline action, and all the phenomena of heaves and faults. The following figure (432) furnishes a good illustration.

It represents a specimen of strings of oxide of tin in slate from St. Agnes, Cornwall, b b, illustrating the heaves alluded to. Sir Henry De la Beche is disposed to refer these to the fact of oxide of tin recementing fractured masses of slate. We think we have sufficient evidence for referring the action to the crystallogenic force enlarging a fissure, or small crack, and producing those lateral cracks, which again, by the operation of the same force, dislocate or heave the original fissure.

In these lodes we find peculiar mechanical arrangements, which are known by various names; a lode is said to be coldly when we have the crystals of quartz or other mineral dovetailing, as it were, with the metalliciferous masses. Branches are isolated masses of ore found in the lode surrounded by earthy minerals. The upper part of a lode is known as its back, and the accumulations of ferruginous matter which very commonly occur in the books and near the surface, are known as gossans. These are to the experienced miner important guides as indicating the characters of the lode at a greater depth. The country signifies, with the Cornish miner, the rock through which the mineral vein runs, and accordingly as he is pleased with the indications he speaks of its being kindly or the contrary. The softer rocks, whether of clay-slate or granite, are spoken of as plum, and a plum grevate, or green, is greatly preferred to the harder varieties, and spoken of as being more kindly.

The rock forming the sides of a lode are known as its walls or cheeks. The latter term we have heard of late years in Cornwall, but we believe it to be imported by miners who have worked in the north of England. As all mineral veins incline more or less, the sides are spoken of as the upper and under walls, the upper being usually termed the hanging wall.

The following wood-cuts (figs. 433, 434) will serve to assist the reader in understanding the peculiarities of mining operations in our metalliciferous mines. In fig. 434, which is a section of one of the lead mines of Cardiganshire, the shafts, which have been sunk on the lode are shown, at varied angles from the vertical and the several horizontal levels. In this instance these levels or galleries have been worked at irregular distances. In Cornwall they are usually ten fathoms apart. The smaller shafts connecting the levels one with the other are called stances. They serve for exploring the lode, or for purposes of ventilation, when the excavations are going forward. When these smaller connected shafts are worked upwards, they are sometimes, they are called "risings," and the miner is said to be working on the "rise." In this wood-cut the lightest shading is to indicate a portion of this particular mine which was worked out by the Romans. The darker shaded masses indicate portions of the lode which have been very productive of metalliciferous matter, and which have consequently been removed. The term counter or counter lode is given to such lodes as dip at a considerable angle with the direction of the other lodes in its vicinity. Such a lode is shown, (fig. 433,) which is, however, inserted principally to explain that where the "underlie" of the lode is great, a vertical shaft is sunk at some distance from it on the surface, so as to "cut" (intersect) the lode at some depth, in this instance at 70 fathoms below the adit-level. As the inclination of the lode then alters, the shaft is continued on the lodes. Another fissure or lode, sometimes called a "dropper," is seen to take nearly a vertical direction from the 50-fathom level, and from the shafts levels are driven into this lode, at about every 10 fathoms.
Fig. 435 represents in plan the underground workings of a Cornish mine. Those who are not familiar with mining are requested to suppose that the earth is transparent so as to enable us to see the levels worked at various depths, from the adit-level—through which the water pumped from the mine is discharged—to the 125-fathom level below it. These levels are numbered in the plan. They are not worked immediately under one another; but, as the lode inclines, in the same way as is shown in the Counter lode, (fig. 433,) they follow in position this underlie of the lode. The dark lines and the dotted lines crossing the numbered lodes, are workings upon lodes, running in a contrary direction to the lode principally shown. This plan shows the junction of the granite with the killas or clay-slate of Cornwall, and the occurrence of elvan courses is shown at the different levels. By studying the plan, with the horizontal and transverse section, the operations of metallicious mining will be understood.
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In all mines, to a greater or a less extent, there will be found accumulations of water; it is necessary, therefore, to adopt measures to ensure its removal. The mineral treasures, being brought to the surface, necessarily undergo a process of "dressing," that is, the separation of the richer from the poorer portion. For a full account of dressing machinery, &c., see ORES, DRESSING OF, AND WATER PRESSURE MACHINERY.

It sometimes happens that the necessities of mining demand the construction of shafts in places covered with water. Some years since a very extraordinary case of this kind was to be seen at the Wherry Mine, near Penzance, where a cylinder of wood, rising through the sea, formed the entrance to a shaft sunk into the mine. In a storm a ship ran against this timber structure and destroyed it.

M. Triger, engineer in the department of Maine and Loire, had the idea of making a well in the very bed of the Loire by means of compressed air. A cylinder of thin iron, (fig. 435a,) served as a cutting machine, was sunk into the alluvium; it was separated into three compartments by horizontal partitions. The upper compartment remained always open, the lower compartment was the workshop, and between them was the middle one, which served as the chamber of equilibrium, designed to be put in communication with either the compartment above or the one below. The things being so disposed, they forced into the bottom compartment, air compressed by a vapor machine without intermission. This air drove the water up a tube, of which the lower part was buried in the bottom of the excavation, and of which the upper part was raised above the cylinder. The workmen were then able to penetrate the first apartment and open the second, which was afterwards hermetically closed, and in which the air of ordinary pressure was put in communication with the compressed air in the third. Having arrived in the third compartment they excavate the sands, and cause the machine to descend. As they accumulate the sands excavated in the middle compartment, they have only to remove them by shutting the communication with the bottom and opening that of the top. A pressure sufficient to balance the exterior waters was maintained during the work, without sensibly incommoding the workmen. This ingenious proceeding has since received numer-
ous applications. In fig. 435a is represented the apparatus as it was used by M. Triger at the bottom of the Loire.

It is evident that wells dug in the water-saturated earths must immediately be cased, that is to say, covered with a casing of wood, solid and impermeable, which is able to resist the infiltration and pressure of the waters at the same time.

A plan similar to this was employed by Mr. Brunel in the construction of one of the piers, in the bed of the river Tamar, for the Royal Albert Bridge at Saltash.

MINT. At the Mint, gold, silver, and copper are converted into coin of the realm, but as the processes are nearly similar, it is only necessary to describe the coining of gold, and to point out briefly the difference in the manufacture of copper coin, because silver undergoes precisely the same operations as gold, the same machinery being used for all three metals. Copper is rolled from red-hot slabs of copper, about 12 inches long by 10 inches broad, and 1 inch thick, by five inches, down to a slab between 3 and 4 feet long, by 14 inches broad, and 0.20 of an inch thick; the slab is then cut in half, digested for 10 minutes in beer grounds, and heated to redness; it is then plunged into cold water as rapidly as possible, by which means the thick scale of red oxide of copper, which forms during the rolling, is separated; but as small particles of the scale still remain, the slabs are scratched by men with brushes made of brass wire until perfectly clean; it is then cut into ribbons or fillets of a convenient width, by a pair of circular shears. Fig. 436 shows these shears, A and B being cogged wheels supported on shafts, which each terminate in plates of iron supporting circular plates of hard steel, E F. The inner surface of F is pressed against the outer surface of E, which is provided with a screw, k, at the extreme end of its shaft for this purpose. D is a cogged wheel reversing the motion which would otherwise be given to n, so as to cause the shears to revolve in opposite directions, and, in fact, the shears may be viewed as endless scissors driven by machinery. The copper slabs are rested on the plate n, and the width of the fillet to be cut is determined by fixing the gauge c at any required point; this having been arranged, the slabs are steadied and pushed lightly against the point at which E F touch, and by the motion of the plates are drawn through and cut or sheared at the same time. Copper fillets do not pass through the drug bench, as is presently explained, for gold. The only other difference in the processes copper undergoes, is that it is blanched by a bath of iron 20 to 30 hours in cold diluted sulphuric acid.

Silver is bought, through the brokers, by the Master of the Mint, either in the form of foreign coin (5-franc pieces are preferred) or ingots, and to the silver so obtained is added so much copper or pure silver, as shall bring the whole mass up to the standard silver of the realm, which consists of 222 parts of silver and 18 parts of copper. The metal so arranged is weighed out into charges of about 4,000 ounces for the wrought-iron melting-pot, which is represented in fig. 437, as seen in the furnace e standing on the "bottom A," which rests on the fire bars, and is made partially cup-shaped and filled with powdered coke, that the bottom of the pot n may be perfectly supported, while at the same time it is protected from the current of air which is supplied to the furnace. Powdered coke, being a bad conductor, prevents the free passage of heat from the base of the pot to the "bottom," and the consequent probable fusion of the two through the agency of the oxide of iron, which forms and accumulates whenever iron is repeatedly heated. n is the lid of the pot, and c the muffle or funnel, against the sides of which the metal rests during the
process of fusion, to prevent its falling over into the burning coke. The pot, when charged, is allowed to remain in the furnace till the metal has fused, and the temperature has risen to a point little short of that which would so far soften the wrought iron pot as to cause it to lose its shape. The pot is lifted by the tongs \( r \), of the crane, 3, from the furnace \( n \), (after the fire has been removed by displacing some of the fire-bars,) swung round and dropped into the cradle \( m \), of fig. 438, when it is secured by a screw, which draws tight the head at the top. The melted silver is then thoroughly stirred with an iron rod, and all being ready, the frame of moulds, \( a \), is run under the cradle stand so far as to allow the rack \( n \) to work into the wheel \( x \). The foreman then, by means of the handle \( p \), which communicates by \( k \) with the cradle in which the pot is fixed, raises the pot, and tilts it so much as is necessary to pour the fluid silver into the mould until it is filled; he then lowers the pot, and waits while an assistant by the handle \( o \), connected with the cog-wheel \( x \), moves the moulds forward as they are required to be filled. The moulds are ranged side by side in the frame, and pressed firmly together by screws at the ends of the mould-frames, and secured in front by two bars of iron, \( q \), which fit into wedge-shaped grooves, slanting forwards.

The metal solidifies immediately, and the pot having been emptied, the carriage of moulds is run on its wheels \( q \), from under the cradle frame, and the screws having been loosened, the moulds are caused to fall to pieces, and each bar, as it is exposed, is taken by tongs and plunged into cold water, as much to save time as to soften the bar by sudden cooling. The bars produced from the whole pot of metal are numbered with a distinctive figure to designate the pot, and with two letters to indicate the day's melting; assay pieces are then cut from the first, middle, and last bars of the set. The assay pieces are properly secured, certified, and sent to the non-resident assayers of the Mint. (For an account of this process, see Assay.) In the event of the assay being unsatisfactory, the pot is stopped, and the metal is adjusted as to quality and remelted. The assays being satisfactory, the bars are forwarded to the coining department, where they undergo the same process of manufacture as gold is subjected to.

Gold is sent by the Bank of England to the Mint in the form of ingots, which average about 180 ounces each, and are assayed by the resident assayers in the Mint, who make a
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report to the Master. The Master directs the addition of so much pure copper, or pure gold, as will make the whole into standard gold, which consists of 22 parts of pure gold and 2 parts of pure copper, making what is technically termed standard gold, and in these proportions the gold, with its alloy, is sent to the melting house.

Since gold requires so high a temperature for its fusion, it would be unwise to attempt to fuse it in iron pots, consequently the so-called black-lead pots (for a description of which see Crucible) are used. Fig. 439 demonstrates the position of the pot as it would appear if in the furnace; 0 represents the "bottom," which is usually obtained by breaking a worn-out pot into a convenient form; 4 is the pot, n the muffle, which, as in the case of silver, answers the purpose of a funnel, to guide the metal during the time of fusion into the pot; c is the top, or lid of the pot. Care is required in using black-lead pots, else the small amount of moisture which they absorb from the atmosphere causes the fracture of the pot when it is suddenly heated, therefore the pot is dried carefully before it is used; and when required for use, is placed in the furnace with a small fire, which gradually increases in temperature to a full white heat, the pot becoming by this process annealed, and is then seldom liable to fracture unless badly used. The pot and furnace being ready, the gold, and its alloy previously weighed out in charges of about 1,500 ounces, but varying slightly according to the size of the ingots which compose the charges, are placed carefully in the pot. As fusion ensues, the molten mass is stirred with a rod made of the same substance as the pot itself. In fusing both standard gold and standard silver, it is customary to place either small pieces of charcoal or powdered charcoal at the bottom of the pot before placing the metal in the pot; then as the metal fuses it runs down and rests upon the fine particles of charcoal; when the fusion is complete, the charcoal is released from the bottom of the pot by the process of stirring, and as it rises balloon-like through the fused or molten mass, it reduces any oxide of copper which may have been formed during fusion, and resting on the surface of the fluid metal protects it from the atmosphere during the time of pouring. The pot is lifted from the furnace after the removal of the fusing by a hand crane, and it is then taken by a pair of long tongs, as shown in fig. 440, by the foreman, who passes the little button at the end of the tongs through a loop of iron, a, suspended by a rope which passes to the ceiling and through a pulley down to an assistant, who by this means bears the weight, and regulates the height of the pot, while the foreman pours the metal into the moulds b, fixed in the frame c, which runs on wheels in a tramway. Three pieces of planed iron form two moulds, as shown in fig. 441, where Ds, s, tmo, show the form of these planed pieces, and the manner of placing them together. The bars are solidified immediately, and when all the moulds have been filled, they are taken to pieces and the bars plunged into cold water, with the same object as in the case of silver. From the bars obtained from each pot, two pieces are cut off for assaying, by the non-resident assayers, the bars being numbered according to the pot from which they were poured, and lettered distinctively, according to the day on which they were melted. Should the assay prove unsatisfactory, the metal is adjusted and remelted. If the assays are satisfactory, the bars are forwarded to the coined depot.

In the coined department the first operations are performed in the rolling room, which is provided with very powerful machinery for driving six pairs of rollers made of chilled cast-iron. Fig. 442 represents one pair of these rollers, which are used for breaking down the bars partially to the form of fillets or ribbons; they are driven by a 40 horse steam-engine, and revolve in opposite directions. A represents the rollers, which are of 14 inches
diameter. The upper one is supported by a pair of strong brasses bolted together, r r. From the lower brass proceeds, as may be seen in fig. 442, a rod n, which passes through the solid massory, and communicates with a counterpoise weight p, placed on a long lever whose fulcrum is s. The object in counterpoising the upper roller is to ensure the removal of all pressure which is not intentionally applied in the process of rolling. r shows a capstan head, the copper ring on which is divided into 50 parts, an indicator being fixed to the main frame of the mill. The handle a moves two endless screws which work into the teeth of the wheels r, which are supported by powerful screws, passing through the main frame of the mill, and touching the upper brass of the upper roller at c. By this means any pressure which is deemed wise can be exerted on a bar placed between the rollers. The sovereign bars are wrought in pairs, and five pairs make one batch, a number of bars which is found most convenient to work at the same time.

A sovereign bar is 21 inches long, 1-375 inch broad, and 1 inch thick. The first process is to submit the bars to six pinches between the rollers, by which they are reduced to 0-194 inch thick, and become 1-712 inch broad, at which stage the hollow ends are sheared off, and the bars are cut into lengths of 18 inches; they are then placed in 5 copper tubes a, as shown in fig. 443, the tops of which are carefully luted on with clay, and the copper tubes are then placed on a small cast-iron carriage n, and run into the annealing furnace c. After 20 minutes' annealing at a full red heat, the carriage is withdrawn; the tubes taken one by one in tongs, and plunged as rapidly as possible into cold water. It is found that rapidly cooling renders gold, silver, and copper soft and tough, while it renders iron and steel hard and brittle. Therefore the more rapidly the gold is cooled, the greater the result as to the softening of the bars. After annealing, the bars go back to the breaking-down mill, and receive six pinches, by which they are reduced to 0-120 inch thick, and 1-778 inch wide, and are now called fillets, and are gauged by a wedge-shaped instrument shown in fig. 444, which is simply a hollow wedge, graduated into thousands of an inch, the great object being to ascertain if both sides of the fillets are of the same thickness, which is done by placing a fillet in the graduated opening between a and n. The bars reduced to 0-120 inch thick, are passed to a finer pair of rollers, under which they receive six pinches, and are then
passed to a still finer pair of rollers, until at last, after 11 pinches, they arrive at the gauging mill, which is as accurate as rollers can be made to be; but at this stage the officer in charge frequently overlooks the professional gauger, and by his gauge tests the fillet in every part, so as to determine that it is of the same thickness throughout its entire length and breadth. Figs. 445, 446 show a plan of the gauge, which is used only by the officer in charge, because it is a most delicate instrument, and is capable of measuring to one ten-thousandth part of an inch, which it gives by a single reading. The instrument was made with great care by Mr. Becker, of the firm of Messrs. Elliott, 30 Strand, and is found practically to give most accurate results. Fig. c shows the point at which any substance to be measured is placed. The upper rod of steel c, rests upon the lower one n, and passes to the handle of the instrument, terminating in a lever n, by which it can at any moment be drawn backward if the lever be pressed by the thumb while the handle a is firmly held by the same hand. The rod c is provided at r with a rack, into which a small pinion works, carrying an indicator e, which traverses over an accurately divided scale with 500 divisions. If now the space of the point p c be opened 0·50 an inch, the indicator travels over the whole 500 divisions on the face, and as the hand itself carries a vernier g, which gives the tenth of a thousandth of an inch, we have by the first reading the division of one inch which indicates the 0·0001 part. The gauge can be used to measure up to 3 inches by drawing back the lever n, until the zero of c points to 500, when the rod c is secured by a clamp at a, and the rods c n are drawn out till the zero of c points to the zero of the dial.
plate; the screws are then again secured, and he proceeds as before. When the fillets leave the gauging mill they must be 2 inches broad, and must not vary 0.000001 of an inch in thickness from one part to another. Besides the examination by the officer, the gauger strikes out occasionally one or two blanks from the fillets, to see that the rollers have not altered; great danger of alteration arising from the fact that the middle of the fillet wears away the roller more than its sides do, so that the middle is evidently liable to become thicker than the sides; and if this fault once arises, it is found to give great trouble in future operations. As the greatest delicacy is required at the gauging mills, another and more accurate system of adjusting is adopted. Fig. 447 shows a side view of the gauging mill: a, b, the rollers; c is a wedge which travels under the brass of the lower roller, which is cut to fit the wedge exactly. The wedge c is forced forward by the gear work f, which sets the screw f in motion, giving the most minute adjustment. At d is an opening to allow the supply of oil to the neck of the upper roller. The fillet as it travels onwards rests on the apron l.

The fillets are now so accurate that a blank struck from any part of them seldom varies more than 0.040 or 0.060 grain, but are left so thick that a blank weighs 8 grains more than a coined sovereign should weigh; the object in leaving it so heavy being that it may undergo far more delicate operations, so as to reduce the variations of thickness as much as possible.

The fillets now pass on to the drag room, where a boy passes them twice through a pair of very delicate adjusting rollers, and another boy trims one end of each fillet by a pair of shears, and passes the end so trimmed into an opening between a pair of rollers, shown at figs. 448, 449, and 450, where the fillet is shown in c as being passed between the revolving rollers a, b, at the time that the surface of n which is cut away presents itself and admits of the free passage of the fillets to the stop or gauge n. As the roller n revolves towards c, it carries the fillet with it, and at the same time reduces the thickness as much as is required. The distance between the rollers a, b is regulated by the pinions e, which turn screws resting on the braces of a. The flattering mill, for so it is called, is driven by a strap passing over the drum n; the shaft of which carries a small pinion g working into f. To relieve the weight, the fillet is rested on l. The end which is called flatted becomes by this pressure about one-third thinner than the other part of the fillet, and it is usual to flat about three inches of the fillet.

The flatted fillets are then taken to the drag bench, where they are made to pass by main force through an opening, in
which is fixed a pair of small cylinders of the hardest steel, exactly fitting into beds which hold them rigidly, and prevent the most minute movement. Figs. 451 and 452 give a full view of the drag bench; a represents drums, over which the endless chain b passes; the

![Diagram](image)

drum a, at the end where it is shown as moved by the cogged wheel c, is cut in deep grooves to the depth of about two inches, and into these grooves the bar of the chain fits so that as the drum revolves it drags the chain with it. The drum at the other end is plain, and is therefore simply a carrier of the chain, which, as it travels on the upper surface of the bench, fits into a trench provided for it. The machine is driven by the drum e, which is connected by its shaft with f, which drives the wheel e, having on its shaft the small wheel n, which finally drives c. There are two drag benches, and each has two chains, so that the wheel r becomes a common motion for two chains. Fig. 452 shows a section of the drag head with the dog in the act of dragging a fillet through the opening x. In using the drag bench the flatted end of the fillet is passed by the hand into the opening between the bars r where the small cylinders are shown at x to be fixed in the blocks p in the opening s; the dog is now brought up by the handle s, until the mouth e is pressed into the opening

![Diagram](image)

x, when the rods i open the jaws, which are cut with a good set of teeth, and seize the end of the fillet as it protrudes. The handle attached to the weight h is then lifted, and e is depressed until its hook catches into a cross-bar of the travelling chain n, when it is drawn on. The dog travels on wheels d, whose axle here becomes a wedge acting upon the long end of c, and so causes the fillet to be held tight in proportion to the resistance offered to its passage between the cylinders. The handle of r is never used, because it is too far for the dragsmen to reach with convenience, but the hooks which catch the chain are shown at f. Fig. 453 gives a further view of the drag head; it consists of a very firm frame of iron provided at the top with an horizontal wheel n which works a fine cut screw. The cylinders are fixed in the blocks n, which are held to their positions by screws at the side; the lower block p is regulated as to height by screws from below, and the upper block b becomes the only movable one. If it is required to bring the cylinders closer together, the dragsman does it by moving the handle o, which communicates by its pinion p with the wheel u. It is almost needless to say that by this arrangement the most minute alterations can be made in the thickness of the fillet, and it frequently happens that so minute an adjustment is made as to show a difference of only half a grain upon 47 sovereign blanks;
and if it be remembered that a thickness of 0.001 inch on a sovereign blank equals 0.125 of a grain, it will be conceived that the distance which the cylinder is made to travel by this most beautiful micrometric arrangement is very small. The drag bench was invented by the late Mr. Barton, and may be viewed as the greatest addition to the machinery of the Mint ever yet or ever likely to be introduced; for by its agency, when intelligently managed, the fillets of silver coming from it are so perfect that for days together the blanks cut from them are found to contain only 1 in 400 out of remedy, and it is quite a common occurrence to find only 1 in 800, and from gold fillets blanks are cut in which only 1 in 100, and even 1 in 200 are rejected as being out of remedy.

To the drag bench are fixed two pairs of hand shears, by which the fillets are cut into four lengths. They are then passed on to the trier, who, by the hand-cutter shown at Fig. 454, punches out one or more blanks from each piece of fillet, and weighs it in a delicate balance placed close beside him. The fillet is placed on the bolster A, and the trier, holding it in the left hand, takes the handle C in his right, and by pulling it towards him causes the screw with which it is provided to depress the cutter N, which, as it travels, cuts a blank and pushes it through A, the trier at the same moment placing his hand under the bench to catch the blank as it falls. The spring D is so powerful as to carry back the handle to its original position while the trier is catching the falling blank. The trier has the most important office in the Mint, and it requires a man with fortitude and a very calm judgment; for although he places the blanks in the scale pan, and goes through the operation of weighing it, he cannot of course spare time to see the exact weight; he therefore forms an opinion of the weight, and so accurate is this opinion that he is never known to produce sovereign blanks which vary more than one grain if forty-seven are weighed at the same time at any time of the day. The result of more than thirty tons of gold coined lately, came out within a very small number (it is believed 8 sovereigns) of the whole value.

After leaving the hands of the trier the fillets are wiped with cotton waste to free them from oil, which is found necessary to prevent the friction of the metal at the time of passing between the cylinders, else it happens that the cylinders get so hot as to cause the skimming off of the surface of the fillet.

The fillets having been cleaned, are taken into the cutting-out room, and are there cut by machinery into blanks and scissel. Fig. 455 represents one of 12 cutting-out presses. It stands on a firm bed, and the frame c is made of solid iron bolted to the bed. Quite independent of the frame of the press, there are a series of iron supports which sustain a strong iron ring, a part of which is shown as having a brass let into it at A. Above this frame is a heavy fly-wheel laid horizontally; between this fly-wheel and the ring or frame is a wheel driven on the same shaft as the fly-wheel, provided with a series of cams or protruding parts. As the wheel revolves the cams strike the wheel p at the end of the lever D. The lever P at its middle is fixed to an upright spindle which passes through the brass
A, and through the frame C, where it is provided with a screw terminating in a socket X, by which the twisting motion of the screw is done away with. The lower end of the socket X is provided with a screw arrangement by which the cutter can, at convenience, be fixed or removed. At q there is an arrangement by which the screw Z, and consequently the socket X, with its cutter, can be brought nearer to or farther from the bolsters which are held in a steel ring secured to the solid base of the press by the screws C, D.

When the press is set in motion by the striking of the cam against R, the cutter is raised from the bolsters. To bring the cutter down again, there is an arrangement by which a rod is attached to the ring U, and terminates in a system of levers which lift a piston fitting in a cylinder hermetically closed (but not shown in the figure); if, therefore, the piston be raised, a vacuum is formed by which means the atmosphere becomes the weight by which the cutter is driven down. The cutter-out is so fixed that when it comes down it just enters the bolster sufficiently to cause the cutting out of the blank with a clean edge. When required for work, the fillet is placed on the bolster, and the workman by his foot touches a treadle which releases the lever p at a, and allows the cutter to come down and punch out a blank, which falls into a box below the bolster, while the fillet from which the blank has been punched or cut travels up till it reaches the guard supported by the screws a, b, which detach it from the cutter. At the end of the lever p is an arrangement supporting s, a block out wedge-shaped, which travels in a circular direction, the distance to which it reaches being regulated by the screw shown near to r. n is a spring made of wood and cut with a slit, into which p passes just at the time that the blank is punched out, when the spring gives the reverse motion, a start which prepares the machine for the blow which will follow by the cam upon r.

The tier and the officer in charge take samples of the blanks from each cutter at frequent intervals and test them against a standard weight, and if it fall a short or fall short of this standard, he makes such alterations of the machinery as are necessary, the object being to produce blanks which are as nearly as possible standard in weight, and not to avail himself of the "remedy" allowed. By the study of this principle the work, as it is called, is brought to the highest perfection. The fillets from which blanks have been cut represent ribbons punched full of round holes, and are now called sealed, which is tied up by a machine worked with a rack and pinion in bundles of 180 ounces, and returned to the melting house.

The blanks are turned out of the boxes into bags and sent to the weighing room, where each blank is weighed by the automaton balance, and its value is determined by weight within a certain limit. See Balance.

The Automaton Balance is the most perfect piece of machinery yet invented, and owes its origin entirely to Mr. Wm. Cotton, of the Bank of England; but it has been adapted to the purposes of the Mint by Messrs. D. Napier & Sons, who have carried its details of manufacture to great perfection. These gentlemen have adopted several improvements which were proposed by Mr. Pilcher, who by his practical use and study of the machines was fitted to point out minute details still wanting to complete the simplicity of the operations to be performed by the machines, that they might give the most accurate results in the shortest possible time. To give an idea of the magnificent workmanship of Messrs. Napier, it is only necessary to say, that after seven years' daily work, the most delicate parts of the balances are still as perfect as when first delivered from their manufactury. For the ordinary purposes of life, the pans of a pair of scales are suspended from the opposite ends of the beam; but if, as is the case in Mr. Cotton's balances, the centres of action are on a line with the centre of gravity, it does not matter at what place the pans are placed so that they are exactly equidistant from the fulcrum or centre knife-edge of the beam; therefore, in figs. 456, 457, 458, the beam A will be seen to rest on its centre knife-edge B, while at the extreme ends of the beam the knife-edges C are facing upwards. The beam, which is of the most exquisite workmanship, is cut from a solid piece of hardened steel. On the inverted knife-edges C, rest planes of hard steel which support the pendant rods D, E, the plane which supports the rod D is surmounted by a disk of polished steel, which forms the pan upon which the blank or coin to be weighed is placed by the automaton hand presently to be described. The rod E is provided at its lower extremity with a cage S, in which is placed the counterpoise or weight, which has to be balanced with the blank placed on the pan or disc of steel F. The rod E terminates in a stirrup H, which passes quite freely through a stand J, supported on delicate micrometric screws. On the stand I is placed a small weight, made of platinum wire, which rests on the stand J, after having been passed through the stirrups H. The stand I is then regulated by its micrometric screws until the weight of platinum wire just touches the upper surface of the stirrup, so that there may be no blow given when the stirrup is not in motion by the beam. When the machine is set in motion by the driving wheels Z, the cam K forces forward the lever L, which moves on pins passed through blocks fixed to the table or base of the machine. At the upper end of the lever L is a provision by which it forces forward an automaton hand or shovel, the end of which is cut into a semi-circle, and is flattened, that it may pass under a gauge into a space
or hopper $m$, which is continued to the height of about two feet, and passes at an angle of about $90^\circ$ over the top of the machine. When the automaton hand is forced forward, the blanks to be weighed are placed in the hopper or shute $m$, and the bottom blank rests on the flattened portion of the hand, but as the cam $k$ forces back the hand or shovel by the...
lever \( \ell \), while at the same instant the forepess \( q \), presently described, release the rod \( b \), the bottom blank falls to the next support, and rests there until the hand or shovel returns, when it is pushed on to the disc \( r \), which is unable to move, because the perpendicular rod \( x \), which is provided at its lower extremity with a horizontal rod, the ends of which pass through a notch or slit cut into the rods \( p \), shown between \( c \) and \( h \) on the rod \( x \) and on the corresponding point of the rod \( b \). At the moment that the blank has been placed on the disc \( r \), the cam \( o \) lifts the rod \( x \) and sets the rods \( p \) at liberty, thus enabling the beam \( \lambda \) to assume the position which it should occupy to indicate the weight of the blank placed on \( e \). The weight having been determined, the motion continues, when the cam \( b \) by a lever \( p \) closes a pair of forepess \( q \), which secure the rod \( b \), while the cam \( a \) allows the indicating finger \( s \) to carry down the indicator \( t \) until the indicating finger \( s \) touches a point provided for it in the rod \( p \). \( t \) is balanced so that its finger has a continual inclination to rise, and is of service to determine the compartment into which the blank shall fall when it is weighed and pushed off by the next blank. The blank falls into and through a shute \( v \), the lower end of which just reaches to three openings on the table on which the machine stands; but at \( v \) it is provided with three inverted steps, one of which steps falls on to the indicating finger \( t \), when the shute is forced outwards by the cam \( w \).

In use the machines weigh to the 0.001 of a grain with certainty, and at the rate of 23 blanks per minute. There are 12 machines driven from a shaft common to all the machines by a small atmospheric engine; but there is attached to each machine at the point where the pulley is connected with the driving wheels \( z \), an arrangement by which the machine throws itself out of motion immediately should any cause arise which would injure or disarrange the works.

The standard weight of a sovereign is 123.274 grains; but the Mint is allowed to issue sovereigns which exceed and fall short of this weight to the extent of 0.2568 grain, which is called the remedy, and allowed because, as before stated, it is impossible to produce coins weighing exactly equal.

Mr. Pilcher suggested, that since it is necessary to determine the weights on both sides of the standard, it would be easy to do this without providing the beam with two remedy weights, as was originally done. The plan now adopted is to reduce the weight used in the casting, which enables the blank to be placed in its own weight, and all which will raise this weight, and yet are not sufficiently heavy to raise with it the weight of platinum wire placed through the stirrups \( h \), and resting on the stand \( i \), are known to be within the weight of the given remedy. Blanks which are too light allow the weight in \( c \) to carry the disc \( p \) upwards, and the forepess \( q \), fixing the point to which the indicating finger will allow the shute to settle, the blank is pushed off by its follower and falls into the shute, which conducts it into the compartment reserved for light blanks. Blanks which are so heavy as to lift the weight in \( c \) and the remedy weight, carry the disc \( r \) downwards, and they are consequently sent into the compartment reserved for heavy blanks. Blanks which are not standard, but which are nevertheless within the latitude of remedy, are called medium, and pass on to be coined.

The three denominations of blanks are frequently tested by a delicate hand balance, to see that the automatic balances are performing their work properly; but in seven years no instance of failure has been detected.

Each machine stands on a planed iron table, and is enclosed by glass sides, which fit down grooves cut in the brass pillars which support the roof of the machine. The roof is made of brass, and supports all the important parts of the machinery.

Thus a standard coin should weigh 123.274 grains to be intrinsically worth a sovereign in value; but since the machinery is not capable of producing two coins in a million of this exact weight, a certain limit or remedy is allowed, and in manufacture the coin may exceed or fall short of the standard weight to the extent of 0.2568 grain. All blanks that come within this limit on either side of the standard are called medium, and presently pass on to be coined, but those which exceed these limits are termed light and heavy rejected; and if the work of the trier has been well performed, these two species of rejected are equal in weight, and the medium if weighed in bulk would be found to be within a few pieces of the standard weight if a million were weighed in bulk and then counted. It is the weighing room which determines the value of the trier's work. The light blanks are returned to the melting house, but the heavy blanks are reduced to the medium weight by a filing machine recently invented by Mr. Pilcher, the officer in charge of this room, and which was made by Mr. Jones in the Mint, under Mr. Pilcher's directions. Fig. 450 shows this machine. \( x \) is a hopper made of brass, and indicated by the dotted lines; it serves to prevent the scattering of the gold dust by the rapid motion of the file. \( n \) is a tube with a slit cut in its upper and in its lower half; \( a \) is a circular file which is made to revolve very rapidly; \( c \) is a knife-edge which offers resistance to the circulating blanks when in motion; \( b \) is a glass dish into which the gold dust as it is filed from the blanks falls. The blanks are arranged en rouleaux in a long scoop, by which they are placed in the tube \( n \). The screws \( o \) are then depressed upon pieces of ebony, previously passed into \( n \), until they just touch the
blanks (as shown by the dotted lines in a.) The knife-edge c, whose weight has been previously adjusted by the weight f, is now allowed to descend on to the blanks and carry them down partly through the tube on to the file. When the file is set in motion the friction gives to the blanks a revolving motion, which is greatly restrained by the weighted knife-edge resting on the top of the blanks, and the resistance offered causes the file to cut the gold away, while the motion of the blanks insures the non-interference with their already perfectly circular form, and the perfect separation of the dust from the blanks. 1,400 blanks are reduced in one minute; and as the dust is carefully collected, loss is unknown.

The medium blanks are carefully rung by being thrown one by one with some force upon a block of iron, and those which do not yield a musical sound are called dumb, and are returned with the light rejected and dust to the melting house. About 2 per cent. is the average yield from all causes, therefore 98 out of every 100 blank struck out in the cutting room ultimately become coined money.

The medium blanks which are now determined to be of the legal weight and sound are forwarded to the marking room, where they are made to undergo a peculiar pressure, which is necessary to raise the edge of the blank preparatory to its receiving the milled edge, because it is found in practice, that unless the edge is prepared, the milling of the edge is not so perfectly effected as is required for the protection of the public or the appearance and good wearing of the coin.

The machine in use at the Mint has answered its purpose for many years, but it is peculiarly liable to get out of order, and as it is probable that it may be replaced, it is thought wise to give a description of the best machine for this purpose, which was invented by Messrs. Ralph Beaton & Sons, of Birmingham, and is now most successfully used by them. Figs. 460, 461, are views of this marking machine: a a is an iron frame in which is a horizontal shaft carrying a driving and a loose pulley and a fly-wheel; b is a flat circular plate with a groove turned in the edge. Fixed to the frame a is a plate c, with a groove cut in its inner edge corresponding to the groove in the plate a. The plate c is adjusted to a by the screws d; e is a hopper into which the blanks to be marked are put; f is a circular plate on which are a series ofcams, which, as they revolve, push back the feeder g, and so allow the blanks to fall from the hopper h. The spring m then brings down
the feeder $a$, which pushes a blank from the bottom of the hopper. The blanks fall down an inclined plane until their edges come between the steel plates $m$ and $e$. The circular plate $n$ revolves, and the pressure of its edge against the blanks carries them forward, and at the same time raises their edges all round to about one-third increased thickness. The parts of this machine are made very rigid, because the blanks as they leave the machine must be perfectly round, or they will not pass freely through the collar in the subsequent process of coinage. The marking machine of Messrs. Heaton marks 400 blanks per minute.

The blanks after having been marked are forwarded to the annealing room to be softened by heat, because they have become, by the processes of manufacture, so hard that unless annealed and softened (it is thought) they would break the dies rather than receive the impression from them. The blanks are placed en rouleaux in iron trays. Each tray holds 2,804 blanks; and when the tray is filled the blanks are covered by an iron plate, which is carefully luted down with clay and then covered with another iron plate which is also luted down. The tray is then placed on a cast-iron carriage and run into the annealing furnace, which is in every respect similar to the furnace shown by fig. 443 in the rolling room. The annealing pans full of blanks are left in the furnace until they have sustained a full red heat for 20 minutes, and are then withdrawn and placed on the floor until the iron pan has lost its red heat, when the tops are removed and the blanks are turned out into a copper pan and carried to the blanching room, where they are thrown into a caldron in cold water, that they may be softened by the rapid cooling. They are then lifted in the caldron into a leaden boiler of boiling sulphuric acid diluted with 2 parts of water. They remain in this bath of diluted sulphuric acid for a few minutes, until the surface of the blanks has become bright and free from the black oxide of copper which has been formed in the course of the process of annealing. At the time of melting a fixed amount of copper is added in addition to the amount of copper which is used to bring the gold to the standard, and this copper, which is called extra alloy, is the exact amount which is removed from the surface of the blanks (forming sulphate of copper) by the process of blanching in dilute sulphuric acid; but, as will be readily understood, if we remove copper from the surface by dissolving it out from an alloy of gold and copper, the gold which remains on the surface must be in a honey-comb or spongy condition, and this thin surface of spongy gold gives to the coin when struck the beautiful bloom which is observed on new coin. In the case of some peculiar gold, the process of annealing the blanks was omitted; and it is probable that this process may ultimately be wholly abolished. After blanching, the blanks are freely washed with cold water to remove all the sulphate of copper from their surfaces, and after washing they are dried by rubbing in a bath of hot box-wood sawdust, which absorbs the wet just as a sponge would; and as the sawdust is thrown upon hot iron plates it soon again becomes dry, and is then ready for the next set of blanks. It is found that sawdust will not remove the last trace of moisture which evidently licks in the substance of the spongy surface of gold, the blanks are therefore thrown into a revolving copper caldron, which fits into a kind of oven, heated to a temperature rather higher than boiling water. They are shaken in this heated atmosphere for about 10 minutes, and are then perfectly dry. It is necessary that the blanks should be absolutely dry before going to the coining room, else they not only make dirty coin, but spoil the dies by destroying the polish on their surface.

The blanks, after leaving the hot-air bath just described, are taken into the press room to receive the impression which renders them the coin of the realm. Next to the weighing machines, invented by Mr. Cotton, the coinage press is the most beautiful piece of mechanism in the Mint. It is automation, and does all that is required of it without the aid of man, and it may even be said to talk, for it is the most noisy of all the Mint machinery. When the eight presses are at work, it is quite hopeless to hear a word spoken. Fig. 462 is a representation of one of these presses. It stands on a solid bed of masonry, and is firmly
bolted down. The massive framework \(c\) is made of cast iron, and is perforated from the top to admit of the passage of a powerful screw which is represented by \(n\) as travelling through the solid mass. \(b\) is continued upwards through the ceiling of the room by a rod of iron which is enclosed by a trumpet-shaped case of iron, represented by \(a\). At the top

of \(a\) is fitted a lever, which drives the press by the agency of the air-pump. The iron rod which continues from \(n\) through \(a\), passes freely through an eye-hole in the lever of \(a\), and is then provided with a swivel joint, which terminates its horizontal motion, while the rod which carries the swivel joint is attached to a long lever, the farther end of which is connected with a piston working in a partly exhausted cylinder, so that when \(n\) is forced down by the action of the air-pump, it necessarily lifts this piston from the bottom of its cylinder, thereby causing a partial vacuum; the atmosphere then pressing on the piston over-balances the weight of \(n\), and returns it to its position, that its lever may again come under the influence of the air-pump. On the bars \(\alpha\) are fitted blocks of iron, wood, wood lined with iron, or iron lined with wood, according to the force of blow required to be given. These blocks simply answer the purpose of a fly-wheel, but striking against a buffer at the
moment that the dies have exerted sufficient force on the blanks, they prevent the destruction of the dies, and give the press a start back again to its original position. At 7 is fixed on a a piece of brass of an eccentric form, which would be best understood if it were described as of the shape a shilling would assume if it were pierced at the point which is supposed to represent the nose of her Majesty, and a slit were then cut in the place of the inscriptions at the back of the head of the same figure, extending from the A of gratia to the n of the r. n. In the slit so described the lever h travels, but as it is fixed on a pivot at 1, that part which travels through the slit becomes the short end of the lever, and in consequence that part which is below 1 is the longest; therefore, when n descends with its circular motion, it also gives the eccentric brass plate 7 a twist and throws the long end of the lever through a considerable proportionate distance. At the lower end of the lever at a, is a brass frame which carries an automaton hand through the slide 8. When the automaton hand is set in motion, it carries a blank from the lower end of the tube k and deposits it in the collar which fits over the lower die, and returns to fetch another blank while the upper die descends to coin the blank just deposited. n receives a motion which carries it through half a circle; but if this twisting motion were given to the upper die, it would render the coin to be produced imperfect, therefore the strong rods e travel through the main frame c, and at their lower ends are provided with brasses, the outer surfaces of which are grooved to fit the wedge shape into which c is cut at this point. The rods e are fixed to n and travel with it, carrying at f an arrangement by which the block 4 is prevented from twisting round. b fits into a socket provided with a brass at 3. The lower die is fixed in a block 5, provided with adjusting screws, and resting on the base 6. The upper die is fixed in the block 4, which, in fact, becomes literally a part of d. When the press is in downward motion, the springs resting on the block 5 lift the milled collar which fits over the neck of the lower die, and causes it to enclose the blocks already placed there while the blow is given; but directly the press starts on its upward journey, the rod e catches to small lever a and forces the collar down on to the shoulder of the lower die, while the automaton hand comes forward and displaces the coin, when it places another blank on the die ready for the next blow of the press.

Fig. 463 gives a view of the milled collar a. b being a representation of the lower die, with its long neck which fits nicely into the milled collar a. c, the upper die, also passes to a small distance into the collar, so that at the moment of the blow the blank is absolutely enclosed. The blow, which is estimated at 40 tons, forces the metal into every engraved part of the collar and dies. The press, which has been described with as few technical terms as possible, coins from 60 to 80 blanks per minute, finishing by one blow the obverse and reverse impressions, and adding the milled edge. (For the manufacture of dies, see Dies.)

The coins when struck are collected at frequent intervals and carefully overlocked to find any which may be defective; for, with all the beauty of the mechanism of the press, accidents cannot be avoided, and it is found that about one coin in 200 is imperfect in its finish, whatever its size or value. The imperfect coins are returned with the ends cut from the bars, the seceded, and the imperfect and out-of-remedy blanks to the melting house every morning. The coins are weighed into bags, each containing 701 sovereigns, and at intervals, depending on the requirements of the Bank, sent to the Mint office, where they undergo that time-honored process of the Pyx, which means that the sovereigns are weighed out into pounds Troy, and their difference plus or minus upon the standard weight is noted, two pieces being taken from each bag. One of these two is placed in a strong box and reserved for the "trial of the Pyx" at Westminster Hall, and the other is divided, and sent to the non-resident assay-ers, who report upon its purity. The coins which are taken are not selected, but culled indiscriminately from the bag full. After assaying (unless the assay should be unsatisfactory) notice is sent to the Bank of England, and at a fixed time an officer comes with a wagon and two porters and fetches the gold coin.
MOHAI.R.

It is only necessary to repeat that silver and gold undergo precisely similar treatment, but it has been omitted to say that the bars for different denominations of coin are of different widths, but all of the same length and thickness as regards silver.

Notwithstanding the inference implied by the company of mon eyers, and the evidence to be found in Blue Books, it is untrue to state that there must be a loss by coining the precious metals. At this present time loss in the coining department is utterly unknown, and this cannot be surprising if the great chemical fact that "matter cannot be lost" be kept in mind; for, however much we may divide a substance, the aggregate of its pieces must again make up the total; so it is with minting, and the minute particles which escape the watchful eyes of the workmen and their officers are recovered in the dust and sweepings of the Mint.

In the process of melting, there is an apparent loss to a small extent, but this is nearly balanced by the money obtained for the sweepings.

When it is stated that there is no loss by coining, it must not be understood that the coining department receives a definite weight of bars, and returns an exactly equivalent weight of coin; as this is not intended to be stated; for it is evident that the extra alloy which is added, that it may be removed by the process of blanching or pickling, must be taken into account, as also must the value of the sweepings. But it is distinctly stated, that if to the coin delivered, the calculated amount of extra alloy and the value of the sweep be added, there is then no loss by coining, although a small margin must be allowed for minute differences in weighing between the different departments. This is positively true as regards gold, but there are some elements of calculation which are omitted, and make it appear that there is a very trifling loss in coining silver; it is nevertheless probable, that some of the silver is volatilized by the many annealings it is submitted to, and its bulk probably gives a greater latitude for differences of weighing. It has long been observed, that when gold coins, which have circulated till they have become "light," are melted and assayed, the ingots are almost invariably below the standard of fineness. This has been attributed to the introduction of base coins; but it seems to be more probably owing to the removal of the surface of pure gold, which is left at the time of blanching, by the wear to which the coins are subjected in circulation.

It must be borne in mind, that the foregoing is not intended for a descriptive account of the Mint machinery, but simply as a faithful relation of the processes adopted to convert bullion into coin—minting as it is at this date. 1838.—G. F. A.

MOHAI.R. is the hair of a goat which inhabits the mountains in the vicinity of Angora, in Asia Minor.

We are indebted for this account of mohair to the History of the Worsted Manufacture of England, by James.

Very much akin to, and in Yorkshire rising into importance about the same time as that of alpaca, the mohair manufacture demands attention.

The goat is amongst the earliest animals domesticated by man, and undoubtedly, from the very earliest ages, the fabrication of stuffs from its hair was practised by the nations of antiquity. Throughout the middle ages the art of making beautiful stuffs from the covering of the goat prevailed.

After the Angora goats have completed their first year, they are clipped annually, in April and May, and yield progressively from one to about four pounds' weight of hair. That of the female is considered better than the male's, but both are mixed together for the market, with the exception of the two-year-old sheepgoat's fleece; which is kept with the picked hair of other white goats (of which, perhaps, 5 lbs. may be chosen out of 1000) for the native manufacture of the most delicate articles; none being ever exported in any unwrought state. Common hair sold in the Angora bazaar for 9 piastres, or about 1s. 6d. the oke (that is, 2½ lbs.), whilst the finest picked wool of the same growth fetched 14 piastres the oke. When the fleeces are short, the women separate the clean hair from the dirty, and the latter only is washed. After which, the whole is mixed together, and sent to the market. That which is not exported raw is bought by the women of the laboring families, who, after pulling portions loose with their fingers, pass them successively through a large and fine toothed comb, and spin it into skeins of yarn, of which six qualities are made. An oke of Nos. 1 to 3 fetched in the Angora bazaar from 24 to 25 piastres, and the like weight of Nos. 3 to 6 from 38 to 40 piastres. Threads of the first three Nos. had been usually sent to France, Holland, and Germany; those of the last three qualities to England. The women of Angora moisten the hair with much spittle before they draw it from the distaff, and they assert that the quality of the thread greatly depends upon this operation.

Formerly there was a prohibition against the export from Turkey of the Angora hair except when wrought, or in the form of homespun yarn; but about the time of the Greek revolution, this prohibition was removed. Up to that period, however, there had been little demand for the raw material in Europe, so that it sold in the year 1829 at only 16d. per pound in England. The reason of the raw material not being in request arose from the belief that, owing to the peculiarity of the fibre, it could not be spun by machinery.
MOIRE.

It soon, however, became apparent that mohair could be thus spun in England, and this was more to be desired, because the Angora mohair yarn had so many imperfections, from being thick and uneven, as to detract greatly from its value. This object, however, has been obtained mainly by the perseverance of Mr. Southey, the eminent London wool-broker. Since then the use of the Angora wool has much extended, whilst the importation has much decreased, the English spun yarn being preferred.

The demand for Angora hand-spun yarn has almost ceased, and its value in Turkey has fallen to one-half. Mohair is now sent to England chiefly from the ports of Smyrna and Constantinople. In color it is the whitest known in the trade, and is consequently peculiarly adapted for the fabrication of a certain class of goods. Besides Angora, quantities of an inferior sort of mohair are received from other parts of Asiatic Turkey—a very fine description of goat's hair is also sent from that country.

In England, mohair is mostly spun, and to some extent manufactured at Bradford, and also in a less degree spun at Norwich. Scotland is also engaged in working up mohair yarn. At first great difficulty occurred in sorting and preparing the material for spinning, but by patient experiment this has been effectually surmounted, and a fine and even thread produced, fitted for the most delicate webs.

The price of Angora goats' hair has, since its importation into this country, fluctuated very much, partly from the variations in demand, and partly owing to the supply. When the wool was first introduced, it realized only 1s. 2d. or 1s. 4d. per pound. During the years 1845 and 1846, it ranged from 1s. 3d. to 1s. 8d. per pound; and about the year 1850 it sold for 1s. 9d. to 1s. 10d. per pound; and now it is sold on the average at 1s. 10d. per pound.

Numerous articles are manufactured from mohair. For instance, many kinds of camlets, which, when watered, exhibit a beauty and brilliance of surface unequalled by fabrics made from English wools. It is also manufactured into plush, as well as for coach and decorative laces, and also extensively for button, buttonings, and other trimmings for gentlemen's coats. Besides, it is made up into a light and fashionable cloth, suitable for paletots, and such like coats, combining elegance of texture with the advantages of repelling wet. A few years since, mohair striped and checked textures for ladies' dresses, possessing unexcelled glaziness of appearance, were in request; but of late these have been superseded by alpaca. For many years the export of English mohair yarn has been considerable to France.

This trade is enjoyed at Bradford and Norwich, but chiefly by the former place. This yarn is manufactured in France into a new kind of lace, which, in a great measure, is substituted for the costly fabrics of Valenciennes and Chantilly. The Angora goats' hair lace is as brilliant as that made from silk, and costing only about 1s. 2d. the piece, has come into very general wear among the middle classes. Mohair is also manufactured into fine shawls, selling from £4 to £16 each. Also large quantities of what is termed Utrecht velvet, suitable for hangings, and furniture linings for carriages are made from it abroad. Recently this kind of velvet has begun to be manufactured at Coventry; and it is fully anticipated that the English made article will successfully compete with the foreign one in every essential quality.

MOIRE is the name given to the best watered silks. These silks are made in the same way as ordinary silks, but always much stouter, sometimes weighing, for equal surface, several times heavier than the best ordinary silks. They are always made of double width, and this is indispensable in obtaining the bold waterings, for these depend not only on the quality of the silk, but greatly on the way in which they are folded when subjected to the enormous pressure in watering. They should be folded in such a manner that the air which is contained between the folds of it should not be able to escape easily; then when the pressure is applied the air, in trying to effect its escape, drives before it the little moisture which is used, and hence causes the watering. Care must also be taken so to fold it that every thread may be perfectly parallel, for if they ride one across each other, the watering will be spoiled. The pressure used is from 60 to 100 tons.—H. K. B.

MORPHINE. Syn. Morphia. (Morphine, Fr.; Morphin, Ger.) C19H21NO4 + 2 H₂O An organic base, obtained (amongst others) in opium. As it is the substance upon which the sedative properties of opium depend, great attention has been paid to its extraction. Numerous processes have been devised for the purpose; but perhaps that of Gregory is, in facility and economy, as good as any. The aqueous infusion is precipitated by chlorid of calcium to remove the meconic and sulphuric acids present. The filtered fluid is evaporated until the hydrochlorate of morphine crystallizes out, so as to form a nearly solid mass, which is then strongly pressed: the liquid exuding contains the coloring matters and several alkaloids. The pressed mass is crystallized and sakeled separately, and, if necessary, bleached with animal charcoal. The hydrochlorate, which contains a little codeine, is to be dissolved in water and precipitated by ammonia; pure morphine precipitates, and the codeine remains in solution. The salts of morphine most employed in medicine are the hydrochlorate, the acetate, and the sulphate. A solution of 5 grains of morphia in 1 ounce of water is about the same strength as laudanum.—C. C. W.
MORTAR. A mixture of lime with water and sand.

The sand used in making mortar should be *sharp*—that is, angular, not round—and *clear*, that is, free from all earthy matter, or other than silicious particles. Hence *road scrapings* always, as being a mixture of sand and mud, and *pit sand* generally, as being scarcely ever without a portion of clay, should be washed before they are used, which is seldom necessary with *river sand*, this being cleaned by the flowing water. "I have ascertained by repeated experiments, that 1 cubic foot of well burned chalk lime fresh from the kiln, weighing 35 lbs., when well mixed with 3½ cubic feet of good river sand, and about 1½ cubic foot of water, produced above 3½ cubic feet of as good mortar as this kind of lime is capable of forming. A smaller proportion of sand, such as two parts to one of lime, is, however, often used, which the workmen generally prefer, but because it requires less time and labor in mixing, which saves trouble to the laborers, and it also suits convenience of the masons and bricklayers better, being what is termed *tougher*, that is, more easily work- ed, but it does not by any means make such good mortar. If on the other hand the sand be increased to more than the above proportion of 3½, it renders the mortar too short; that is, not plastic enough for use, and causes it also to be too friable, for excess of sand prevents mortar from setting into a compact adhesive mass. In short, there is a certain just proportion, between these two ingredients which produces the best mortar, which I should say ought not to be less than 3, nor more than 3½ parts of sand, to 1 of lime; that is when common chalk lime, or other pure limes are used, for different limes require different proportions. When the proportion of sand to lime is stated to be in the above manner, which is done by architects as a part of their specification, or general directions for the execution of a building, it is always understood, when nothing is expressed to the contrary, that the parts stated are by fair level measure of the lime, and by stricken measure for the sand; and that the lime is to be measured in lumps, in the same state in which it comes from the kiln, without slaking, or even breaking it into smaller pieces."—Pedley.

*MOSAIC.*—(Mosaico, Fr.; *Mosaik*, Germ.) There are several kinds of mosaic, but all of them consist in imbedding fragments of different colored substances, usually glass or stones, in a cement, so as to produce the effect of a picture. The beautiful chapel of St. Lawrence in Florence, which contains the tombs of the Medici, has been greatly admired by artists, on account of the vast multitude of precious marbles, jaspers, agates, aventurines, malachites, &c., applied in mosaic upon its walls. The detailed discussion of this subject belongs to a treatise upon the fine arts. The progress of the invention is so curious that some brief notice of mosaic work in general will not be out of place.

When, with his advancing intelligence, man began to construct ornamental articles to decorate his dwelling, or to adorn his person, we find him taking natural productions, chiefly from the mineral kingdom, and combining them in such a manner as will afford, by their contrasts of color, the most pleasing effects. From this arose the art of mosaic, which appears, in the first instance, to have been applied only to the combination of dice-shaped stones (*tesserae*) in patterns. This was the *opus musicum* of the Romans; improving upon which, we have the Italians introducing the more elaborate and artistic *pietra dura*, now commonly known as Florentine-work. It is not our purpose to treat of any of the ancient forms of mosaic-work, further than it is necessary to illustrate the subject before us. The *opus tessellatum* consisted of small cubes of marble, worked by hand into simple geometrical figures. The *opus sectile* was formed of different crusts or slices of marble, of which figures and ornaments were made. The *opus vermiculatum* was of a far higher order than these: by the employment of differently-colored marbles, and, where great brilliancy of tint was required, by the aid of gems, the artists produced imitations of figures, ornaments, and pictures, the whole object being portrayed in all its true colors and shades.

The advance from the *opus vermiculatum* to the fine mosaic work, which had its origin in Rome, and is, therefore, especially termed Roman mosaic, was easy; and we find this delicate manufacture arising to a high degree of excellence in the city where it originated, and to which it has been almost entirely confined, Venice being the only city which has attempted to compete with Rome. To this Art-manufacture we more especially direct attention, since a description of it will aid us in rendering intelligible the most interesting and peculiarly novel manufacture of mosaic rug-work, as practised by the Messrs. Crossleys. Romano, and also Venetian enamels, are made of small rods of glass, called indiscriminately *paste and smalt*. In the first place, cakes of glass are manufactured in every variety of color and shade that are likely to be required. These cakes are drawn out into rods more or less attenuated, as they are intended to be used for finer or for coarser works, a great number being actually threads of glass. These rods and threads are kept in bundles, and arranged in sets corresponding to their colors, each division of a set presenting every desired shade. A piece of dark slate or marble is prepared, by being hollowed out like a box, and this is filled with plaster of Paris. Upon this plaster the pattern is drawn by the artist, and the *mosaisti* proceeds with his work by removing small squares of the plaster, and filling in these with pieces cut from the rods of glass. Gradually, in this manner, all the plaster is removed and a picture is formed by the *end of the filaments of colored glass*; these are
carefully cemented together by a kind of mastic, and polished. In this way is formed, not only those exquisitely delicate mosaics which were at one time very fashionable for ladies' brooches, but tolerably large, and often highly artistic pictures. Many of our readers will remember the mosaic landscapes which rendered the Italian Court of the Great Exhibition so attractive; and in the Museum of Practical Geology will be found a portrait of the late Emperor of Russia, which is a remarkably good illustration of mosaic-work on a large scale. We may remark, in passing, that the whole process of glass mosaic is well illustrated in this collection.

The next description of mosaic work to which we will direct attention is the manufacture of Tumbridge. The wood mosaics of Tumbridge are formed of rods of wood, varying in color, laid one upon the other, and cemented together, so that the pattern, as with the glass mosaics, is produced in the ends of the rods.

**Mosaic Wool Work.** There is no branch of manufacture which is of a more curious character than the mosaic wool work of the Messrs. Crossleys of Halifax.

By referring to the article Mosaic, there will be no difficulty in understanding how a block of wood, which has been constructed of hun dred of lengths of colored specimens, will, if cut transversely, produce a great number of repetitions of the original design. Suppose, when we look at the transverse section presented by the end of a Tumbridge block, we see a very accurately formed geometric pattern; this is rendered perfectly smooth, and a slab of wood is glued to it. When the adhesion is secure, as in a piece of veneering for ordinary cabinet-work, a very thin slice is cut off by means of a circular saw, and then we have the pattern presented to us in a state which admits of its being fashioned into any article which may be desired by the cabinet-maker. In this way, from one block, a very large number of slices can be cut off, every one of them presenting exactly the same design. If lengths of worsted are substituted for those of glass or of wood, it will be evident that the result will be in many respects similar. By a process of this kind the mosaic rugs—with very remarkable copies from the works of some of our best artists—are produced. In connection with this manufacture, a few words on the origin of this kind of work will not be out of place.

The tapestries of France have been long celebrated for the artistic excellence of the designs, and for the brilliancy and permanence of the colors. These originated in France, about the time of Henry IV., and the manufacture was much patronized by that monarch and his minister Sully. Louis XIV. and Colbert, however, were the great patrons of the beautiful productions of the loom. The minister of Louis bought from the Brothers Gobelin their manufacture, and transformed it into a royal establishment, under the title of *Le Tisselier Pavillon*. A work was published in 1746, in which it was seriously told that the dyers of the Gobelins had acquired such superiority that their contemporaries attributed the talent of these celebrated artists to a paction which one or the other of them had made with the devil.

In the Gobelin and Beauvais Tapestry we have examples of the most artistic productions, executed with a mechanical skill of the highest order, when we consider the material in which the work is executed. The method of manufacture involving artistic power on the part of the workman, great manipulatory skill, and the expenditure of much time, necessarily removes those productions from the reach of any but the wealthy. Various attempts have been made, from time to time, to produce a textile fabric which should equal those tapestries in beauty, and which should be sold to the public at much lower prices. None of these appear to have been successful until the increasing applications of India-rubber pointed to a plan by which high artistic excellence might be combined with moderate cost. In Berlin, and subsequently in Paris, plans—in most respects similar to the plan we are about to describe—were tried; but in neither instance with complete success. Of course, there cannot now be many of our readers who have not been attracted by the very life-like representations of lions and dogs which have for the last few years been exhibited in the carpet warehouses of the metropolis, and other large cities. While we admit the perfection of the manufacture, we are compelled to remark that the designs which have been chosen are not such as appear to us to be quite appropriate, when we consider the purposes for which a rug is intended. Doubtless from their very attractive character, and moderate cost, these rugs find a large number of purchasers, by whom they are doubtless greatly admired. It will, however, be obvions to our readers, that they are not consistent with the principles of design, and that there is a want of consistency in the idea of treading upon the "monarch of the forest," copied with that remarkable life-likeness which distinguishes the productions of Sir Edwin Landseer; or in placing one's feet in the midst of dogs or of poultry, when the resemblances are sufficiently striking to impress you with the idea that the dogs will bark, and that the cock will crow. We believe that less picturesque subjects, in accordance with the law—which we conceive to be the true one—which gives true beauty only to that which is, in its applications, consistent and harmonious, would be yet greater favorites than those rugs now manufactured by the Messrs. Crossleys. And amidst the amount of good which these excellent men are doing to all who come within their in-
fluence, we are certain they might, with the means at their command, introduce an arrangement of colors which might delight by their harmonious blending, and a system of designs which, pure and consistent, should ever charm the eye, without attempting to deceive either it or any of the senses. Every attempt to advance the taste of a people is worthy of all honor; and having the power, as the manufacturers of the mosaic rugs have, of producing works of the highest artistic excellence, we should be rejoiced to see them employing that power to cultivate amongst all classes a correct perception of the true and the beautiful.

With these remarks we proceed to a description of the manufacture.

Every lady who has devoted herself for a season, when it was the fashion to do so, to Berlin wool-work, will appreciate the importance of a careful arrangement of all the colored worsteds which are to be used in the composition of her design. Here, where many hundreds of colors, combinations of colors, and shades are required, in great quantities and in long lengths, the utmost order is necessary; and the system adopted in this establishment is in this respect excellent. We have, for example, grouped under each of the primary colors, all the tints of each respective color that the dyer can produce, and between each large division the mixtures of color producing the neutral tones, and the inter-blending shades which may be required to copy the artist with fidelity. Skeins of worsted thus arranged are ever ready for the English mosaicisti in rug-work. Such is the material. Now to describe the manner of proceeding. In the first place an artist is employed to copy, of the exact size required for the rug, a work of Landseer's or any other master, which may be selected for the purpose. Although the process of copying is in this case mechanical, considerable skill is required to produce the desired result. This will be familiar to all who have observed the peculiar characteristics of the Berlin wool-work patterns. The picture being completed, it is ruled over in squares, each of about twelve inches. These are again interlined with small squares, which correspond with the threads of which the finished work is to consist. This original being completed, it is copied upon lined paper by girls who are trained to the work, each girl having a square of about twelve inches to work on. These are the copies which go into the manufactory. A square is given to a young woman whose duty it is to match all the colors in wool. This is a task of great delicacy, requiring a very fine appreciation of color. It becomes necessary in many cases to combine two threads of wool, especially to produce the neutral tints. It is very interesting to observe the care with which every variety of color is matched. The worsteds are taken, and a knot or knob being formed, so as to increase the quantity of colored surface, it is brought down on the colored picture; and, when the right shades have been selected, they are numbered, and a corresponding system of numbers are put on the pattern. In many of the rugs one hundred colors are employed. The selector of colors works under the guidance of a master, who was in this case a German gentleman, and to his obliging and painstaking spirit we are much indebted. Without his very exact description of every stage of the process, it would not have been easy to render this rare mosaic-work intelligible to our readers. When all the colored woods have been selected, they are handed, with the patterns, to young women, who are termed the "mistresses of a frame," each one having under her charge three little girls.

The "frame" consists of three iron stands, the two extreme ones being about 200 inches apart, and the other exactly in the middle. These stands are made of stout cast iron, and may be said to consist of two bowed legs, with two cross-pieces of iron, one at the top of the legs, and the other about fifteen inches below, the space between them being that which is to be occupied by the threads of wool which are to form the required square block of wool. These frames are united together by means of cast-iron tubes, running from end to end. The observer is struck with the degree of strength which has been given to these frames. It appears that, for the purpose of merely holding together a few threads of wool, a much slighter frame might have been employed; and we certainly were surprised when we were informed that, at first, many frames were broken, and that they were compelled to have the stronger ones at present in use. The cause of this will be obvious, when we have proceeded a little further with our description. At one end of these frames sits the "mistress," with a stand before her, on which the pattern allotted to her is placed, and a vertical frame, over which the long colored worsteds are arranged. By the side of this young woman sits a little girl, who receives each worsted from the mistress, and hands it to one of two children, who are on either side of the frame. Commencing at one corner of the pattern, a thread is selected of the required color, and handed to the first girl, who passes it to the second, whose duty it is to twist it a stiff, but slight bar of steel, about half an inch in width, which passes from the upper to the under bar of the frame. The third girl receives the thread, and carries it to the lower end of the frame, and fastens it to a similar bar of steel at that end. The length of each thread of worsted is rather more than 200 inches. It is well known that twisted wool does not lie quite straight, without some force is applied to it; and of course the finished pattern would be incomplete, if all the threads did not observe the strict parallelism to each other.
To effect this, a stretching force equal to four pounds is required to every thread. The child who carries the thread, therefore, pulls the worsted with this degree of force, and fastens it over the steel bar. Every block, forming a foot-square of rug-work, consists of fifty thousand threads; therefore, since every thread pulls upon the frame with a force equal to four pounds, there is a direct strain to the extent of 250,000 pounds upon the frame. When this is known, our surprise is no longer excited at the strength of the iron-work; indeed, the bars of hardened steel, set edgeways, were evidently bent by the force exerted.

Thread after thread, in this way, the work proceeds, every tenth thread being marked by having a piece of white thread tied to it. By this means, if the foreman, when he examines the work, finds that an error has been committed, he is enabled to have it corrected, by removing only a few of the threads, instead of a great number, which would have been the case, if the system of marking had not been adopted.

This work, requiring much care, does not proceed with much rapidity, and the constant repetition of all the same motions through a long period would become exceedingly monotonous, especially as talking cannot be allowed, because the attention would be withdrawn from the task in hand. Singing has therefore been encouraged, and it is exceedingly pleasing to see so many young, happy, and healthy faces performing a clean and easy task, in unison with some song, in which they all take a part. Harmonious arrangements of color are produced, under the cheerful influence of harmonious sounds. Yorkshire has long been celebrated for its choristers, and some of the voices which we heard in the room devoted to the construction of the wool-mosaics bore evidence of this natural gift, and of a considerable degree of cultivation.

The "block," as it is called, is eventually completed. This, as we have already stated, is about a foot square, and it is 200 inches long. Being bound, so as to prevent the disturbance of any of the threads, the block is cut by means of a very sharp knife into ten parts, so that each division will have a depth of about 20 inches. Hearth-rugs are ordinarily about eight feet long, by about two feet wide, often, however, varying from these dimensions. Supposing, however, this to represent the usual size, twelve blocks, from as many different frames, are placed in a box, with the threads in a vertical position, so that, looking down upon the ends, we see the pattern. These threads are merely sustained in their vertical order by their juxtaposition. Each box therefore, will contain 800,000 threads. The rug is now, so far as the construction of the pattern is required completed; and the cost of producing the "block," of 200 inches in depth, eight feet in length, and two feet wide, including the cost of wool, and the payment for labor, is little short of £800. When, however, it is known that these threads are subsequently cut into the length required to form the rug, and that these lengths are but the three-sixteenths of an inch in depth, it will be evident that the number of those beautiful carpets which can thus be obtained, renders the manufacture fairly remunerative. The boxes into which the rugs are placed are fixed on wheels, and they have movable bottoms; the object of which will be presently understood. From the upper part of the immense building devoted to carpet manufacture, in which this mosaic rug-work is carried on, we descend with our rug to the basement store. Here we find, in the first place, steam chests, in which India-rubber is dissolved in camphene. It may not be out of place to observe that camphene is actually spirits of turpentine, carefully rectified, and deprived of much of its smell by being distilled from either potash or soda. Recently prepared camphene has but little of the terebinthinous odor, but if it is kept long, and especially if it is exposed to the air, it again acquires, with the absorption of oxygen, its original smell. This is of course avoided in the manufacture of such an article as a hearth-rug as much as possible. The camphene is used as fresh as possible, and in it the India-rubber is dissolved, until we have a fluid about the consistence of, and in appearance like, carpenter's glue.

In an adjoining room were numerous boxes, each one containing the rug-work in some of the stages of manufacture. It must now be remembered that each box represents a completed rug—the upper ends of the threads being shaved off, to present as smooth a surface as possible. In every stage of the process now all damp must be avoided, as wool, like all other porous bodies, has a tendency to absorb and retain moisture from the atmosphere. The boxes, therefore, are placed in heated chambers, and they remain there until all moisture is dispelled; when this is effected, a layer of India-rubber solution is laid over the surface, care being taken, in the application, that every thread receives the proper quantity of the caoutchone; this is dried in the warm chamber, and a second and a third coat is given to the fibres. While the last coat is being kept in the warm chamber, free from all dust, sufficiently long to dissipate some of the camphene, the surface on which the rug is to be placed receives similar treatment. In some cases ordinary carpet canvas only is employed; in others, a rug made by weaving in the ordinary manner is employed, so that either side of the rug can be turned up in the room in which it is placed. However this may be, both surfaces are properly covered with soft caoutchone, and the "hacking" is carefully placed on the ends of worsted forming the rug in the box. By a scraping motion, the object of
which is to remove all air-bubbles, the union is perfectly effected; it is then placed aside for some little time, to secure by rest that absolute union of parts, between the two india-rubber surfaces, which is necessary. The separation of the two parts is after this attended with the utmost difficulty; the worsted may be broken by a forcible pull, but it cannot be removed from the india-rubber. The next operation is that of cutting off the rug; for this purpose a very admirable, but a somewhat formidable machine is required. It is, in principle, a circular knife, of twelve feet diameter, mounted horizontally, which is driven, by steam-power, at the rate of 170 revolutions in a minute.

The rug in its box is brought to the required distance above the edge of the box, by screwing up the bottom. The box is then placed on a rail, and connected with a tolerably fine endless screw. The machine being put in motion, the box is carried by the screw under the knife, and by the rapid circular motion, the knife having a razor-like edge, a very clean cut is effected. As soon as the rug is cut off, to the extent of a few inches, it is fastened by hooks to strings which wind over cylinders, and thus raise the rug as regularly as it is cut. This goes on until the entire rug is cut off to the thickness of three sixteenths of an inch. The other portion in the box is now ready to receive another coating, and the application of another surface, to form a second rug, and so on, until about one thousand rugs are cut from the block prepared as we have described.

The establishment of the Messrs. Crossley, which gives employment to four thousand people, is one of those vast manufactories of which England may proudly boast, as examples of the industry and skill of her sons. Here we have steam engines urging, by their gigantic throes, thousands of spindles, and hundreds of shuttles, and yet, notwithstanding the human labor which has been saved, there is room for the exertion of four thousand people. The manner in which this great mass of men, women, and children is treated, is marked in all the arrangements for their comfort, not merely in the great workshop itself, but in every division of that hill-encompassed town, Halifax. Church, schools, and park proclaim the high and liberal character of those great carpet manufacturers, one division, and that a small one, of whose works we have described.

MOULDS, ELASTIC. Being much engaged in taking casts from anatomical preparations, Mr. Douglas Fox, surgeon, Derby, found great difficulty, principally with hard bodies, which, when undercut, or having considerable overlaps, did not admit of the removal of moulds of the ordinary kind, except with injury. The difficulties suggested to him the use of elastic moulds, which, giving way as they were withdrawn from complicated parts, would return to their proper shape; and he ultimately succeeded in making such moulds of glue, which not only relieved him from all his difficulties, but were attended with great advantages, in consequence of the small number of pieces into which it was necessary to divide the mould. The body to be moulded, previously oiled, must be secured one inch above the surface of a board, and then surrounded by a wall of clay, about an inch distant from its sides. The clay must also extend rather higher than the contained body; into this, warm melted glue, as thick as possible so that it will run, is to be poured, so as to completely cover the body to be moulded: the glue is to remain till cold, when it will have set into an elastic mass, just such as is required.

Having removed the clay, the glue is to be cut into as many pieces as may be necessary for its removal, either by a sharp-pointed knife, or by having placed threads in the requisite situations of the body to be moulded, which may be drawn away when the glue is set, so as to cut it out in any direction.

The portions of the glue mould having been removed from the original, are to be placed together and bound round by tape. In some instances it is well to run small wooden pegs through the portions of glue, so as to keep them exactly in their proper positions. If the mould be of considerable size, it is better to let it be bound with moderate tightness upon a board to prevent its bending whilst in use; having done as above described, the plaster of Paris, as in common casting, is to be poured into the mould, and left to set.

In many instances wax may also be cast in glue, if it is not poured in whilst too hot, as the wax cools so rapidly when applied to the cold glue that the sharpness of the impression is not injured.

Glue has been described as succeeding well where the elastic mould is alone applicable; but many modifications are admissible. When the moulds are not used soon after being made, treacle should be previously mixed with the glue (as employed by printers) to prevent its becoming hard.

The description thus given is with reference to moulding those bodies which cannot be so done by any other than an elastic mould; but glue moulds will be found greatly to facilitate casting in many departments, as a mould may be frequently taken by this method in two or three pieces, which would, on any other principle, require many more. The preparation of Murexide is one of those substances which, although investigated by many chemists of great reputation, has long been regarded as of uncertain constitution. This is the more remarkable from the fact that,
Owing to its extreme beauty, it has always attracted a large amount of attention. It is invariably formed when the product of the action of moderately strong nitric acid on uric acid is treated with ammonia. The process, however, is rather valuable as a test of the presence of uric acid, than as a method of procuring murexide. Dr. Gregory, who has given much attention to the best methods of preparing the substance in question, has published the following formula for working on the small scale:—"Four grains of aloxantine and seven grains of hydrated aloxan are dissolved together in half an ounce by measure of water by boiling, and the hot solution is added to one-sixth of an ounce by measure of a saturated or nearly saturated solution of carbonate of ammonia, the latter being cold. This mixture has exactly the proper temperature for the formation of murexide; and it does not, owing to its small bulk, remain too long hot. It instantly becomes intensely purple, while carboueic acid is expelled; and as soon as it begins to cool, the beautiful green and metallic-looking crystals of murexide begin to appear. As soon as the liquid is cold, these may be collected, washed with a little cold water, and dried on filtering paper.

The analyses of murexide are rather discordant, the carbon in all of them being in excess. This arises from the very large amount of nitrogen present, a certain portion becoming acidified passes into the potash apparatus, causing an undue increase in its weight.

There appears no doubt whatever that the formula $C_6N_3H_4O_6$ represents its true composition. Murexide is formed when uranic, murexane, or diuranide, as it is sometimes called, is boiled with peroxide of mercury. Dr. Gregory regarded murexane as a separate substance, and as identical with purpuric acid: he also considered $C_6N_3H_4O_6$ as its probable formula. This appears from more recent researches to be incorrect, as murexane is doubtless the same substance as uranic, while purpuric acid, which is dibasic, is represented by the formula $C_6H_4N_2O_2$. The formula above given for murexide and uranic renders the reaction of peroxide of mercury with the latter easily intelligible; it is, in fact, a very simple case of oxidation, thus:—

$$2C_6N_3H_4O_6 + 20\text{H}_2\text{O} \rightarrow 2C_6N_3H_4O_6 + 2\text{H}_2\text{O}$$

Uranic. Murexide.

The limits of this work preclude any further notice of the scientific relations of murexide, but it is necessary that we should consider it in its character as a dye-stuff. It has been found that murexide forms a series of beautiful compounds with certain metallic oxides, more especially lead and mercury, and these compounds have been employed to a very large extent in the dyeing, and more especially printing of cotton goods. It is plain that if uric acid were only obtainable from the urine of serpents or the sediments from the urine of mammals, it could never be made use of in the arts. It happens, however, that the solid urine of birds contains it in large quantity, and since we have become acquainted with the vast deposits of guano existing in various parts of the globe, the manufacture of murexide has been carried out on a scale which would, a few years ago, have appeared impossible. We must, in order to be clear, divide the process into two parts, one being the preparation of uric acid from guano, the other the conversion of the acid into murexide.

Preparation of uric acid from guano.—In order to get rid, as much as possible, of the impurities contained in the guano, it is in the first place to be treated with muriatic acid, which will remove carbonate and oxalate of ammonia, carbonate and phosphate of lime, and ammonium-magnesian phosphate. The uric acid will also be liberated from the substances with which it may be in combination. The operation may be performed in a leaden vessel, heated with a leaden coil, through which steam passes. It is essential to succeed that the guano be added slowly, otherwise the violent effervescence, which is caused by the decomposition of the carbonates by the acid, would cause the liquid to escape from the vessel. The mixture of guano and muriatic acid is then to be heated for an hour, after which it may be run off into tubs, to be washed with water by decantation. The first washings contain a large quantity of ammonia in the state of sal ammoniac; it should be worked up in some way, in order to prevent the loss of so valuable a salt. As soon as the residue of the guano is sufficiently washed, it may be transferred to cloth filters and allowed to drain. The residue from the action of muriatic acid upon 200 lbs. of guano can now be treated by Braun's process for the extraction of the uric acid. It is to be placed in a copper boiler of sufficient capacity, and boiled for an hour with 8 pounds of caustic soda and 120 gallons of water. It must be constantly stirred. Two or three pounds of quicklime are now to be added, enough water is then to be added to make the whole into a thin paste, which is to be poured into the mixture of caustic soda and guano residue. After a quarter of an hour's boiling, the fire is to be removed and the whole allowed to repose until clear. The bright liquid having been siphoned off from the residue, the latter is to be treated with 120 gallons more water and 6 pounds of soda; 2 pounds of slaked lime are also to be added in the same manner as in the first operation. The lime is for the purpose of removing extractive matter, and it has been found that it does not do to use it in any other manner than that described. If the soda and lime be allowed to react upon the guano residue at the same
time, urate of lime is formed, which, owing to its comparative insolubility, causes much trouble in the subsequent operations.

The two alkaline fluids containing the urate of soda are to be precipitated while warm by a moderate excess of hydrochloric acid. The precipitated uric acid is then to be washed with water and dried.

**Conversion of the uric acid into murexide by Brown's process.**—In the first place, a very large bath of cold water must be provided, having a number of earthenware basins floating upon it. Into each of these basins 2½ pounds of nitrates of soda are to be poured, the strength of the acid being 30° Beaumé. One pound and three quarters of the uric acid, prepared as above, is now to be added by very small quantities at a time. If the temperature rise above 90° F. the whole is to be allowed to cool before adding any more uric acid. If the water in the bath be so cold that the temperature falls so low as to stop the reaction, it may be set up again by adding warm water to the bath, or, more conveniently, by sending some steam into it for a short time. At first the uric acid need only be added to the nitric acid by sprinkling it on the surface, towards the end of the operation; when the nitric acid has become enfeebled, it is necessary to stir it in. The quantity of mixture contained in two basins is now to be placed in an enamelled iron pot on a sand-bath. As the heat increases the fluid will boil up in the pot, and to prevent loss the vessel must be removed from the fire for a short time. The heating is to be repeated in this manner until the temperature rises to 218° F., and, after removing the pot to the coolest part of the sand-bath, half a pound of liquid ammonia is to be stirred in quickly. In a few minutes the whole is converted into what is called in commerce by the name of *Murexide en poudre*. To convert this into the purer product known as *Murexide en pâte*, it is to be repeatedly stirred up with water and filtered, to remove the saline and extractive matters.

In dyeing cotton by means of murexide, it is necessary to use lead and mercury as mordants. Liquor's process consists in fixing oxide of lead upon the fibre by first immersing it in a bath of acetate of lead, and then in ammonia, or by a bath of oxide of lead and lime. The dye is then mixed with permanganate or perchloride of mercury and a little acetate of soda, and the cotton goods are worked in it for a sufficient time.

For printing, the murexide is mixed with thickened nitrate of lead, and the cloth after printing is dried and subsequently passed through a bath, containing 100 litres of water, 1 kilogramme of corrosive sublimate, and 1 kilogramme of acetate of soda. In Sagar and Schultz's patent process they pad the cotton goods in a solution of murexide with 6 pounds of nitrate of lead in 8 gallons of water, to which cold 6 ounces of corrosive sublimate dissolved in 2 gallons of water are added. The goods are dried after dyeing in the above solution, and the color is fixed by again padding in a solution of wheaten starch, gum, gum substitute, or any similar substance.

Silk may easily be dyed in a bath of murexide mixed with corrosive sublimate. Wool, after being well washed and rinsed, is to be dyed in a strong bath of murexide, and then dried. It is after this to be treated, at a temperature of 104° to 122° F., with a bath containing 60 grammes of corrosive sublimate, 75 grammes of acetate of soda, and 10 litres of water. — C. G. W.

**MUSLIN. To render it and other fabrics non-inflammable.** This very important inquiry was committed by Professor Graham, at the desire of Her Majesty, to the care of Dr. Oppenheim and Mr. Frederick Versmann, from whose report the following important conclusions have been abstracted. After naming many salts found to be useless, or nearly so, they proceed: — "With regard to sulphate of ammonia, the cheapest salt of ammonia, a solution containing 7 per cent. of the crystals, or 6-2 per cent. of sulhydrous salt, is a perfect anti-flammable. In 1839, the Bavarian embassy at Paris caused M. Chevalier to make experiments before them with a mixture of borax and sulphate of ammonia, as recommended by Chevalier, in preference to the sulphate alone. He thought the sulphate would lose part of its ammonia, and thereby give rise to the action of sulphuric acid upon the fabric. This opinion seems to be confirmed by the fact that a solution of sulphate of ammonia gives off ammonia, as observed by Dr. R. A. Smith in his paper on substances which prevent fabrics from flaring; but on the other hand, this may be easily counteracted by adding a little carbonic of ammonia, and besides, the solid salt remains perfectly undecomposed. The authors say that they now have kept for six months whole pieces of muslin prepared in various ways with this salt, some having been even ironed; but cannot find that the texture was in the least degree weakened. Chevalier's mixture, on the contrary, became injurious to the fabric, not only at temperatures above 218°, but even at summer heat; and this can easily be explained, because he did not actually apply sulphate of ammonia and borax, but bichromate of ammonia and sulphate of soda."

Another drawback of Chevalier's mixture is the roughness which it gives to the fabric, and which could only be overcome by calendering the pieces, while sulphate of ammonia by itself has not this effect. The use of this salt must therefore be strongly recommended.

Of all the salts experimented upon, only four appear to be applicable for light fabrics.
These salts are the
1. Phosphate of ammonia.
2. The mixture of phosphate of ammonia and chloride of ammonium.
3. Sulphate of ammonia.
4. Tungstate of soda.

The sulphate of ammonia is by far the cheapest and the most efficacious salt, and it was therefore tried on a large scale. Whole pieces of muslin (eight to sixteen yards long) were finished, and then dipped into a solution containing 10 per cent. of the salt, and dried in the hydro-extractor. This was done with printed muslins, as well as with white ones, and none of the color gave way, with the sole exception of musdrder purple, which became pale. But even this change might be avoided, if care be taken not to expose the piece while wet to a higher than ordinary temperature. Most of these experiments were made at the works of Mr. Crum and of Mr. Coolman. The pieces had a good finish, and some of them were afterwards submitted to Her Majesty for inspection, who was pleased to express her satisfaction.

Mr. Crum, who prepared some dresses with phosphate and some with sulphate of ammonia, arrives at the result, that, with the phosphate, the finish is chalky, and not transparent enough, whereas the finish with the sulphate is successful.

Other pieces, prepared with the sulphate, were exhibited in the Exhibition of Inventions of the Society of Arts, and at the Conversazione of the Pharmaceutical Society, in July last. During the space of six months none of the fabrics prepared with sulphate of ammonia have changed either in color or in texture; it may therefore be considered as an established fact that the sulphate of ammonia may be most advantageously applied in the finishing of muslins and similar highly inflammable fabrics.

The authors felt, however, the necessity of inquiring further into the effect which ironing would have upon fabrics thus prepared; for all the above mentioned salts, being soluble in water, require to be renewed after the prepared fabrics have been washed.

Now, the sulphate of ammonia does not interfere with the ironing so much as other salts do, because a comparatively small portion is required; but still, the difficulty is unpleasant, and sometimes a prepared piece, after being ironed, showed brown spots like iron-moulds. On covering the iron with plates of zinc or brass, these spots did not appear; but the difficulty still existed, and a white precipitate covering the plate, showed evidently that it is the volatile nature of the salt which interferes with the process. An attempt to counteract this action of the salt, by adding wax and similar substances to the starch, remained also without any result.

For all laundry purposes, the tungstate of soda only can be recommended. This salt offers only one difficulty, viz., the formation of a bitungstate, of little solubility, which crystallizes from the solution. To obtain a constant solution, this inconvenience must be surmounted; and it was found that not only phosphoric acid, in very small proportion, keeps the solution in its original state, but that a small percentage of phosphate of soda has the same effect.

The best way of preparing a solution of minimum strength is as follows:—A concentrated neutral solution of tungstate of soda is diluted with water to 28° Trudde, and then mixed with 3 per cent. of phosphate of soda. This solution was found to keep, and to answer well; it has been introduced into Her Majesty's laundry, where it is constantly being used.

The effects of the soluble salts having been thus compared, a few remarks are necessary respecting the means which may be adopted permanently to fix anti-flammable expedients, so that the substances prepared may be wetted without losing the property of being non-inflammable.

Relying upon the property of alumina as a mordant, we tried the combination of oxide of zinc and alumina, obtained by mixing solutions of oxide of zinc in ammonium and of alumina in caustic soda; but although this precipitate protects the fibre, it does not adhere to it when washed.

The oxychloride of antimony, obtained by precipitation from an acid solution of chloride of antimony by water mixed with only a little ammonia, is a good anti-flammable, and it withstands the action of water, but not that of soap and soda. It was not found that the solution of this and other salts in muriatic-acid injured the texture of the fabric, as long as this was dried at an ordinary temperature.

The borate and phosphate of protoxide of tin act effectually, if precipitated in the fibre from concentrated solutions of these salts in muriatic acid by ammonium; they withstand the influence of washing, but give a yellow tinge to the fabrics.

The same remarks apply to arseniate of tin. The stannates of lime and zinc protect the fabric, but do not withstand the action of soap or soda.

The oxides of tin give a favorable result, insomuch as they really can be permanently fixed; the yellow tinge, however, which they impart to the fabrics will always confine their application to coarse substances, such as canvas, sail-cloth, or ropes.
### Table I.

*Showing the smallest percentage of Salts required in Solution, for rendering Muslin Non-inflammable: A, of Crystallized; B, of Anhydrous Salts. Twelve square inches of the Muslin employed weighted 38.4 grains.*

<table>
<thead>
<tr>
<th>Name of Salts</th>
<th>A.</th>
<th>B.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caustic soda</td>
<td>8</td>
<td>6-2</td>
<td>Injurious to the fabrics.</td>
</tr>
<tr>
<td>Carbonate of soda</td>
<td>27</td>
<td>10</td>
<td>Not sufficiently efficacious; too volatile.</td>
</tr>
<tr>
<td>Carbonate of potash</td>
<td>12-6</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Bicarbonate of soda</td>
<td>6</td>
<td>5-4</td>
<td>Destroys the fabrics above 212° Fahr.</td>
</tr>
<tr>
<td>Borax</td>
<td>23</td>
<td>13-2</td>
<td>Injures the appearance of the fabrics.</td>
</tr>
<tr>
<td>Silicate of soda</td>
<td>-</td>
<td>15-5</td>
<td>Not sufficiently efficacious.</td>
</tr>
<tr>
<td>Phosphate of soda</td>
<td>50</td>
<td>32</td>
<td>A concentrated 72 p. c. solution is insufficient.</td>
</tr>
<tr>
<td>Sulphate of soda</td>
<td>20</td>
<td>18-5</td>
<td>Destroys the fabrics.</td>
</tr>
<tr>
<td>Bisulphate of soda</td>
<td>25</td>
<td>10-3</td>
<td>Recommended on account of its being the only salt not interfering with the ironing of the fabrics.</td>
</tr>
<tr>
<td>Sulphite of soda</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tungstate of soda</td>
<td>20</td>
<td>16</td>
<td>Injurious.</td>
</tr>
<tr>
<td>Stannate of soda</td>
<td>20</td>
<td>15-9</td>
<td>Concentrated solutions are insufficient.</td>
</tr>
<tr>
<td>Chloride of sodium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride of potassium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyanide of potassium</td>
<td></td>
<td>10</td>
<td>Poisonous.</td>
</tr>
<tr>
<td>Sesquicarbonate of ammonia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxalate of ammonia</td>
<td></td>
<td>5</td>
<td>Not available.</td>
</tr>
<tr>
<td>Biborate of ammonia</td>
<td>5</td>
<td>3-6</td>
<td>Destroys the fabrics above 212°.</td>
</tr>
<tr>
<td>Phosphate of ammonia,</td>
<td></td>
<td>10</td>
<td>Expensive, but expensive.</td>
</tr>
<tr>
<td>Phosphate of ammonia and soda</td>
<td>15</td>
<td>9-8</td>
<td>Very efficient, and recommended on account of its low price.</td>
</tr>
<tr>
<td>Sulphate of ammonia</td>
<td>7</td>
<td>6-2</td>
<td>Deliquescent.</td>
</tr>
<tr>
<td>Sulphite of ammonia</td>
<td>10</td>
<td>9</td>
<td>Not sufficiently efficacious.</td>
</tr>
<tr>
<td>Isodate of ammonium</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronide of ammonium</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thouret's mixture</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride of barium</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride of calcium</td>
<td>19-7</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Sulphate of magnesia</td>
<td>50</td>
<td>24-3</td>
<td></td>
</tr>
<tr>
<td>Sulphate of alumina</td>
<td>15</td>
<td>7-7</td>
<td></td>
</tr>
<tr>
<td>Potash — alum</td>
<td>33</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Ammonia — alum</td>
<td>25</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Sulphate of iron</td>
<td>54</td>
<td>28-8</td>
<td></td>
</tr>
<tr>
<td>Sulphate of copper</td>
<td>18</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Sulphate of zinc</td>
<td>20</td>
<td>11-2</td>
<td></td>
</tr>
<tr>
<td>Chloride of zinc</td>
<td>8</td>
<td>5-8</td>
<td></td>
</tr>
<tr>
<td>Protocloride of tin</td>
<td>5</td>
<td>4-6</td>
<td></td>
</tr>
<tr>
<td>Protocloride of tin and ammonium</td>
<td>15</td>
<td>4-7</td>
<td>Becomes yellow, when exposed to the air.</td>
</tr>
<tr>
<td>Pine salt</td>
<td>3</td>
<td></td>
<td>Injures the fabric.</td>
</tr>
</tbody>
</table>

### Table II.

*Showing the increase in weight of Muslin prepared with various anti-flammable expedients.*

<table>
<thead>
<tr>
<th>Muslin (not starched) prepared with a solution of</th>
<th>Increased in weight about</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 per cent. of sulphate of ammonia</td>
<td>18 per cent.</td>
</tr>
<tr>
<td>10 per cent. of tungstate of soda</td>
<td>27 per cent.</td>
</tr>
<tr>
<td>12 per cent. of Thouret's compound</td>
<td>24 per cent.</td>
</tr>
</tbody>
</table>
NAPHTHA.

The canvas thus prepared must be dried and then washed, to remove the excess of precipitate. Salt water does not remove the tin from the canvas.

piece about forty yards in length has been prepared by order of the storekeeper-general of the Royal Navy; but it was found to have lost in strength, and increased in weight too much, to allow of its application.

These experiments, however, being the first successful attempts permanently to fix some anti-flammable agents, may have some interest, although they leave but little hope that the result of fixing anti-flammable expedients will ever be obtained without injuring the fabrics.

By determining the comparative value, and ascertaining the difficulties which have prevented, till now, the general use of protecting agents, the authors were led to exclude a number of salts hitherto proposed, and to advocate the adoption of sulphate of ammonia, and of tungstate of soda, in manufactories of light fabrics, and in laundries.

They hope, therefore, that the general introduction of these salts will soon greatly reduce danger and loss of life through fire.

In the manufacturing process the weight increases at a somewhat higher rate; a piece of starched tafata, weighing about 8½ oz., took up about 2 oz. of sulphate of ammonia from a 10 per cent. solution.

Dr. Oppenheim and Mr. Versmann have received a certificate from Messrs. Cochran and Dewar, at the Kirkton Bleach Works, Neilston, who bear witness to the perfect success of the process for rendering muslins non-inflammable, by the application of sulphate of ammonia. They have finished many pieces of the finest muslins by this process, and the texture of the cloth is in no way injured; while neither color nor elasticity is materially changed.

The manager of the Queen's laundry expresses entire satisfaction with the action of the solution (namely, of tungstate of soda) for rendering light fabrics, such as curtains, muslin dresses, &c., non-inflammable. After having tested various salts and solutions intended for the purpose, this is the only one found to be neither injurious to the texture or color, nor in any degree difficult of application in the washing process. The iron passes over the material quite smoothly, as if no solution had been employed. The solution increases the stiffness of the fabric, and its protecting power against fire is perfect. The writer says that many specimens have been submitted to her Majesty, who was highly pleased with them, and has commanded that the solution be used in the laundry for every thing liable to danger from fire.

NAPHTHA. By the term naphtha, we understand the inflammable fluids produced during the destructive distillation of organic substances. Formerly the term was confined to the fluid hydrocarbons, which issue from the earth in certain parts of the world, and appear to be produced by the action of a moderate heat on coals or bitumens. The term has now, however, become so extended as to include most inflammable fluids (except perhaps turpentine) obtained by distillation from organic matters. We shall study the various naphthas under the following heads:

Naphtha (Boghead or Bathgate).

" (Bone or Bone Oil).

" (Caoutchouc or Caoutchoucine).

Naphtha (Coal).

" (Native).

" (Shale).

" (Wood).

For the methods of preparing and purifying naphthas in general, see NAPHTHA, COAL; also PHOTOGEN.—C. G. W. NAPHTHA, BOGHEAD OR BATHGATE. Syn. Photogen, Paraffine Oil. For several years a naphtha has existed in commerce under the above name. It is now prepared on an immense scale in various parts of the Old and New World. It was, we believe, at first procured solely by the distillation, at as low a temperature as possible, of the Torbanhill mineral or Boghead coal, but now it has been ascertained that any cannel coal, or even bituminous shale, if subjected to the same treatment, will yield identical products.

Photogen may be recognized at once by its low specific gravity, the ordinary kinds (boiling between 290° and 480°) having a density of about 0.750; whereas coal naphtha cannot be brought by any number of rectifications below 0.850.

The less volatile portions of the first runnings of photogen contain a considerable quantity of paraffine, so much so, indeed, that the oil is extensively used, under the name of paraffine oil, for lubricating machinery. A mixture of the more and less volatile portions is employed for burning.

Preparation of crude paraffine oil.

The following is an outline of the process employed by Mr. James Young. The best coals for the purpose are Parrot, cannel, and gas coals, and especially the Boghead coal.
NAPHTHA.

It is well known that the latter yields a very large quantity of asphaltic residuum, when burned in an open fire or distilled; this does not, however, interfere in the least with its value as a source of photogen. It is convenient, previous to placing the coals in the still, to break them into fragments of the size of hen's eggs, this operation enabling the heat to penetrate more readily throughout the mass. The apparatus for distillation merely consists of an ordinary gas retort, from the upper side of which a condensing pipe passes to the condensing arrangement. The latter must be moderately capacious, and not kept cooler than 55° Fahr. The reason of this is, that if too small or too cool, the paraffine is likely to accumulate and choke up the exit pipe. When the retort has been closed in the ordinary manner, it is to be heated to a low red, but not higher, until no more volatile products distil over. If the heat rises above the temperature indicated, a considerable loss is incurred, owing to formation of too large a quantity of olefiant and other gases. The retort must be allowed to cool down considerably before the insertion of a fresh charge, otherwise much is lost before the joints are made tight.

Mr. Young states that instead of driving over the whole of the fluid by distillation in the manner described, a portion may be conveyed at once from the still by having an opening in its lower part communicating with a pipe passing to some convenient recipient. By this arrangement, the products of the coal are removed from the still the moment they have assumed the liquid form. It is preferable, however, in almost all cases, to distil the hydrocarbons over in the manner first mentioned.

The product of the operation conducted as above is crude paraffine oil. It will sometimes begin to deposit paraffine when the temperature has only fallen to 40°. During distillation a certain quantity of gas is necessarily produced, but it is essential to economical working that the amount should be as small as possible. To effect this, care must be taken not only to use as low a temperature as is consistent with the distillation of the oil, but also to apply the heat gradually and steadily. See Photogen.

Purification of the crude paraffine oil for lubricating purposes.

The oil is run into a tank and heated by a steam pipe to about 150° F. This causes the water and mechanically-suspended impurities to separate. The fluid should be permitted to repose for about twelve hours before being run off. The impurities and water (owing to their being specifically heavier than the paraffine oil) remain at the bottom of the settling tank.

The crude oil, after separation of the mechanically-suspended impurities, is then to be distilled in an iron still attached to a condenser, kept at a temperature of 55°, with the precautions to prevent choking up, which were previously described. The distillation is conducted by the naked fire, until no more can be driven over. The dry coke-like mass which remains in the still is to be removed before making a fresh distillation.

To each 100 gallons of this distillate, 10 gallons of commercial oil of vitriol are to be added, and the mixture is to be well mixed for about one hour. The apparatus best adapted for this admixture is described in the article NAPHTHA (Coal). After the thorough incorporation of the oil and acid, the whole is to be allowed to rest for about 12 hours, to enable the acid "sludge" to sink to the bottom of the vessel. The fluid is then to be run off into another vessel (preferably of iron), and, to each 100 gallons, 4 gallons of caustic soda, of the specific gravity 1:300, is to be added. The soda and oil are then to be well incorporated by agitation for an hour, so as to thoroughly neutralize any acid which has not settled out, and also to remove certain impurities which are capable of combining with it.

The oil so purified is a mixture of various fluid hydrocarbons, to be presently described, holding in solution a considerable quantity of paraffine. The more volatile hydrocarbons may be removed by the following process:—

The purified paraffine oil is to be placed in an iron still, connected with a condensing arrangement. The still is then to have run into it a quantity of water, about equal to half the bulk of the oil, and this distillation is to be continued for 12 hours. It is obvious that a great portion of the water would distil over, if not replaced during the progress of the distillation. It is preferable to perform the distillation by means of direct steam. A volatile cold fluid will distil over with the water. . . . The naphtha so procured is lighter than water, and soon separates from it. It contains little or no paraffine. The oil remaining in the still is, of course, richer in paraffine by the amount of naphtha removed, and the separation of the solid hydrocarbon is facilitated greatly by the process. The naphtha which distils over with the water in the above process, is the fluid, the chemical nature of which is fully described in this article. A very volatile spirit may be extracted from it, by rectifying it in the apparatus recommended for benzole in the article NAPHTHA (Coal).

The further purification of the paraffine oil is managed as follows:—After separation from the water it is run off into a leaden vessel, and 2 gallons of sulphuric acid added for each 100 gallons of oil. The mixture is to be well incorporated for 6 or 8 hours, after which it is allowed to remain quiet for 24 hours, in order that the acid and any combined impurities may settle to the bottom of the tank. The oil is then to be carefully run off into
another tank, and to each 100 gallons 28 lbs. of chalk ground with water to a thin paste are to be added. The whole is to be mixed together until every trace of sulphurous acid is removed, and is then kept at about 100° for a week, to permit impurities to settle. The oil thus prepared is fit for lubricating purposes, either pure or mixed with an animal or vegetable oil.

Young's process for separating paraffine from paraffine oil.

Mr. James Young extracts paraffine from the oil prepared as above by cooling it to 30° or 40° Fahr. The lower the temperature, the larger the amount which crystallizes out. It may be obtained sufficiently pure for lubricating purposes by merely filtering off and squeezing out fluid impurities from the mass by powerful pressure.

The paraffine may be purified further by alternate treatments at about 150° Fahr. with oil of vitriol and caustic soda. The treatments with acid are to be continued until the latter produces no more blackening. The solid hydrocarbon is then to be washed with caustic soda until all acid is removed, and then with boiling water. The treatment with boiling water should be performed several times.

The oil from which the paraffine has been removed by exposure to cold is by no means freed from the whole of the solid; it is, in fact, a saturated solution of paraffine at the temperature to which it was exposed. It is sometimes advantageous, before extraction by cold, to concentrate the paraffine in the paraffine oil, by subjecting the latter to distillation, until one-half or two-thirds of the fluid has distilled over; by this means the yield of paraffine is proportionately increased.

The amount of solid matter distilling over with naphthas may be seen by consulting the results obtained by MM. Warren de la Rue and Hugo Müller, in their fractional distillation of Rangoon tar. It is to be observed that solid hydrocarbons differ in the degree to which they pass over with the vapor of fluid hydrocarbons. Thus while pyrene and chrysene only appear among the very last products of the distillation of coal at high temperature, naphthas will often distil off at very moderate temperatures in presence of volatile fluid hydrocarbons. The author of this article has repeatedly seen considerable quantities distil over in a current of steam at the pressure of the atmosphere, and consequently at 212°. The facility with which solid hydrocarbons pass over in the vapor of volatile fluids, depends not only upon their boiling points, but also to some extent upon special tendencies varying with the nature and state of admixture or combination of the substances operated on.

On the chemical nature of the fluid hydrocarbons constituting Boghead naphtha.

It has been said, in the above condensed account of the process for preparing paraffine oil from coal, that when the crude oil is rectified with water, a clear transparent naphtha is obtained. This fluid, as found in commerce, is by no means of constant quality. By quality, we mean the power of distilling between given limits of temperature. Some kinds are of about the same degree of volatility as commercial benzole, while others distil at nearly the same temperatures as common coal naphtha. The hydrometer is not a safe guide in choosing this naphtha; this arises from the fact that photogene, of very different degrees of volatility, have almost the same densities. The safest plan is to put the fluid into a retort, having a thermometer in the tubulature, and distil the contents almost to dryness. The careful observation of the range of the mercurial column during the operation is the best mode of ascertaining the quality of the fluid.

The more volatile portions which distil over with water, are free from solid bodies, and consist of a mixture of fluids belonging to three series of homologous hydrocarbons, namely, The benzole series; The olefiant gas or CH₂ series; and The radicals of the alcohols. As no works on chemistry contain any directions for the proximate separation of complex mixtures of hydrocarbons, the following description of the method adopted by the author of this article for the separation of the substances contained in Boghead naphtha may be useful. It is necessary, in the first place, to determine whether each substance is to be obtained in a state of absolute purity, or whether it is merely desired to obtain the various series distinct from each other. In the process given, it will be supposed that the individual hydrocarbons are required in a state of purity, because it is easy for the operator to leave out any part of the method which may be unnecessary under the particular circumstances of the case. The first step is to obtain constant boiling points, for it must be remembered that if, when any organic fluid is subjected to distillation with a thermometer in the tubulature of the retort or still, the mercury continues to rise as the fluid comes over, it is at once demonstrated that the substance distilling is not homogeneous. In order to obtain the fluids of constant boiling point, it is essential to subject them to a complete series of fractional distillations. This is an operation involving great labor, so much so, that in investigating Boghead naphtha, upwards of one thousand distillations were made before tolerably constant boiling points were secured. In order to perform the operation successfully, two series of bottles are required, one for the series being distilled, and the other for the series
distilling. As many bottles are necessary as there are 10-degree fractions to be obtained. Thus, supposing the fluid, when first distilled, came over between 10° and 290°, and it has been determined to obtain 10-degree fractions, the receiver is to be charged for every 10° that the mercury rises. Thus 10 bottles will be required for the fractions distilling, and the same number for the fractions being distilled into. The operation will be commenced by pouring the original fluid (dried carefully with chloride of calcium or sticks of potash) into a retort capable of holding at least half as much more fluid as the quantity inserted. Through the tubulature passes a pierced cork, supporting a thermometer, the lower end of which should not dip into the fluid. To the neck of the retort is adapted a good condensing arrangement, so placed that the bottles can be placed beneath the exit pipe. All the bottles having blank paper labels attached, the distillation is to be commenced. The first signs of distillation are to be watched for, but no fluid is to be separately received as an individual fraction until boiling has commenced. As soon as it is found that the mercury indicates 10° more than the temperature at which the distillation commenced, the bottle is to be changed, and so on at every 10°. When the whole fluid is distilled away, a small retort is to be taken, capable of well holding each 10-degree fraction, without fear of any thing boiling over. Suppose the first fraction of the first distillation came over between 100° and 110°, it is to be placed in the retort, and the distillation carried on as before. But it will be found in every instance, if we found that the boiling point will have been reduced 50° or 40° by the removal of the fluids of higher boiling point. Under any circumstances, however, the distillate is to be received in bottles, and labelled with the boiling point and the number of the rectification. When all the first 10-degree fraction has distilled away into the second series of bottles, the next is to be operated on, and so on. By this means only two series of boiling are ever being used at once; viz., the series being distilled and the series being distilled into. Many fluids may be obtained of steady boiling point by 15 or 16 rectifications, involving, in the case of 10 fractions in each series, at least 150 distillations. But most complex organic fluids, such as naphthas, have a much wider range of boiling point than 100°. Boghead naphtha, for example, commences at about 285° F., and rises above 500°. But in the second distillation, the first fraction, instead of distilling at 290°, came over at 250°, the depression of boiling-point being nearly 40°. By proceeding in this manner six times, a fraction was obtained boiling at 210°. When a 10-degree fraction no longer splits up during distillation, that is to say, when it comes over almost between the same points at which it last distilled, it will be proper to commence the separation of the various substances present in each fraction. Before doing this, it is often advisable to make a few preliminary experiments, with the view of ascertaining the nature of the fluids present. The more volatile portions may be tested for benzole by converting them into aniline in the method given in the article Benzole. The simplest way of detecting the C,H, series (homologous with olefiant gas) will be by ascertaining whether the naphtha is capable of decolorizing weak bromine water. Supposing the presence of these to have been demonstrated, the complete separation of the hydrocarbons may be effected as follows:—Four or five ounces of bromine are to be placed in a large flask, capable of being closed with a well fitting stopper. About 8 volumes of water are then added, and the naphtha of the most volatile fraction is to be poured in by very small portions, the contents of the flask being well shaken after each addition. By this mode of proceeding, the dark color of the bromine will gradually fade and finally disappear. In order to insure a complete reaction, it is better at this stage to add a little more bromine, until the color is permanent after shaking. A little mercury is now to be poured in, and agitated with the fluids in the flask, to remove all excess of bromine. The oily bromine compound is now to be separated, by means of a tap funnel, from the mercury and water, and digested with chloride of calcium until every trace of water is removed. The dry brominated oil is now to be distilled, when the radical and benzole series of hydrocarbons will distil away, leaving the brominated oil, which may then be distilled into a vessel by itself. The next step will be to separate the radicals from the benzole series. For this purpose long-necked assay flasks are necessary. Into one of these vessels, of 3 or 4 ounces capacity, 2 drachms of nitric acid should be poured; 1 drachm of the naphtha is then to be added by very small portions, the flask being kept cool by immersion in cold water. It is essential during the whole time to keep the flask in active motion, in order to bring the hydrocarbon and acid into close contact, and also to cool the contents. If this precaution be neglected a violent reaction will occur and cause the loss of the greater portion of the fluid. When the whole of the drachm of acid has been added, and it is found that the temperature no longer rises on removing the flask from the cold water, the product is to be poured into a narrow and conical glass, and allowed to repose until the hydrocarbon, unacted on, rises to the surface in the form of a transparent brilliant green fluid. The fluid below is then to be removed by means of a pipette, furnished at the upper end with a hollow elastic ball of vulcanized caoutchouc. By this means suction with the lips becomes unnecessary, and the vapors of hypobromite are prevented from irritating the lungs. The indifferent hydrocarbon—that is, the fluid unacted on by the acid—is as yet
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by no means pure; it obstinately retains traces of the benzole and C\(^{14}\) series. It is, therefore, to be transferred to a flask furnished with a well fitting stopper, and treated with nitric acid (spec. grav. 1.5) a considerable number of times. This second treatment may, without danger of any explosive reaction, be made upon one or two ounces of the partially purified hydrocarbon. When it is found that the separated nitric acid no longer produces milkiness on being thrown into water, it may be assumed that the benzole and C\(^{14}\) class of hydrocarbons are entirely removed. When the treatment with acid has been repeated a sufficient number of times, the fluid is to be placed in a clean flask and well agitated with a solution of caustic potash, which will remove the nitrous vapors which are the cause of the green color. The purified hydrocarbon is then to be separated by a tap drawn from the water, and dried by digestion with sticks of caustic potash. If it be desired to obtain the radical in a state of absolute purity, it must be distilled three or four times over metallic sodium.

The indifferently hydrocarbons obtained by the above process are colorless mobile fluids, having an odor somewhat resembling the flowers of the white thorn. They are very volatile, even at low temperatures, and have an average density of about 0.718. When the fractions with proper boiling points have been selected, it will be found that they correspond in specific gravity, percentage composition, and vapor density with the radicals of the alcohols, as will appear by the following table, where the experimental results obtained by the author of this article in his examination of Boghead naptha are compared with the numbers found by other observers with the radicals obtained by treatment of the hydrofide ethers by sodium, and also by the electrolysis of the fatty acids.

**Comparative Table of the Physical Properties of the Alcohol Radicals, as obtained from Boghead Naphtha, with those procured from other sources.**

<table>
<thead>
<tr>
<th>Radicals</th>
<th>Formula</th>
<th>Boiling Points, Fahr.</th>
<th>Density</th>
<th>Vapor Densities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>C(^{3})H(^{6})</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Butane</td>
<td>C(^{3})H(^{8})</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Amylene</td>
<td>C(^{3})H(^{11})</td>
<td>78°</td>
<td>98°</td>
<td>50°</td>
</tr>
<tr>
<td>Caproyle</td>
<td>C(^{3})H(^{12})</td>
<td>82°</td>
<td>108°</td>
<td>33°</td>
</tr>
<tr>
<td>Butyle</td>
<td>C(^{3})H(^{10})</td>
<td>110°</td>
<td>135°</td>
<td>3°</td>
</tr>
<tr>
<td>Amyle</td>
<td>C(^{3})H(^{11})</td>
<td>110°</td>
<td>135°</td>
<td>3°</td>
</tr>
<tr>
<td>Caproyle</td>
<td>C(^{3})H(^{12})</td>
<td>114°</td>
<td>139°</td>
<td>3°</td>
</tr>
</tbody>
</table>

It has been said that the above hydrocarbons distilled away from the bromine compound in company with others which were removed by treatment with nitric acid. It was subsequenctly found that the products formed by the action of the acid were nitro-compounds belonging to the benzole series. The bromine compound contains the C\(^{14}\) series of hydrocarbons, the individual member being determined by the boiling point of the fraction selected for experiment. If we select that portion boiling steadily between 160° and 170°, we shall have a bromine compound of the formula C\(^{14}\)H\(^{14}\)Br; but if the boiling point of the naptha lies between 180° and 190°, the bromine compound will be C\(^{14}\)H\(^{14}\)Br\(^{2}\). It is exceedingly remarkable that if either of these substances be treated alternately with alcoholic potash and sodium, the original hydrocarbon is regenerated. By the mode of operating indicated above it is possible, therefore, to obtain two out of the three series of hydrocarbons in a pure state. The third, namely the benzole series, must be recognized by obtaining products of decomposition.

The acids and bases accompanying the hydrocarbons in Boghead naptha have not yet been fully investigated; it has, however, been ascertained that certain members of the phenole series of acids and pyridine class of bases are always present. The quantities present in the naptha of commerce are small in consequence of the purification of the fluid by the agency of oil of vitriol, followed by a treatment with caustic soda.—C. G. W.

NAPHTHA, Bone. Syn. Bone Oil; Dippel's Animal Oil. This fluid is procured in large quantities during the operation of distilling bones for the preparation of animal charcoal. The hydrocarbons of bone oil have not as yet been examined, but it has been found that the benzole series are present, accompanied by large quantities of basic oils. The acid portions are also uninvestigated. The bases have been very fully studied by Dr. Anderson, who discovered in bone oil the presence of no less than ten bases, several of them being quite new.

The odor of bone oil is exceedingly offensive and difficult of removal. It does not arise entirely from the presence of the powerfully smelling bases, for even after repeated treat-
ment with concentrated acids it retains its repulsiveness. This is partly owing to the presence of some unknown neutral nitrogenous bodies. When a slip of deal wood is moistened with hydrochloric acid and held over a vessel of crude bone oil, it rapidly acquires a deep crimson tint. This is in consequence of the presence of the extraordinary basic substance pyrrol. The latter, when in a crude state, possesses a most disgusting smell, so much so, that the offensiveness of bone oil was at one time mainly attributed to its presence. It has, however, been recently discovered that pyrrol when perfectly pure has a most fragrant and delightful perfume, somewhat recalling that of chloroform, but still more pleasing.

The basic portion of bone oil may be extracted by shaking it up with moderately strong oil of vitriol. This must be done with precaution, as large quantities of gases are evolved, consisting of carboxic acid, hydro sulphuric and hydrocyanic acids. The fluid when permitted to repose separates into two layers, the upper being the purified oil, and the lower the acid solution of the bases. The latter being separated is to be distilled until about one-third has passed over. This distillate will contain the chief portion of the pyrrol. The head of the still is then to be removed and the fluid boiled for some time, to remove the last trace. The acid solution, after filtration through charcoal, is to be supersaturated with lime and distilled. The distillate contains the whole of the bases. The apparatus should be so arranged that those bases which are excessively volatile, and consequently come over as gases, may be received in hydrochloric acid. The hydrochloric solution and the oily bases are to be examined separately. The former is to be evaporated carefully to the crystallizing point and then allowed to cool. By this means the ammonia may be removed by crystallization as chloride of ammonium.

When no more sal-ammoniac can be obtained by crystallization, the mother liquid is to be treated with potash, in an apparatus so arranged that any gaseous products evolved may be collected in hydrochloric acid. The retort must have a thermometer in the tubulation to enable the temperature to be properly regulated. All the bases distilling below 212° are to be received in hydrochloric acid, and their presence demonstrated by converting them into platinum salts, and fractionally crystallizing. The bases distilling above 212° are to be separated by fractional distillation. An examination of the hydrochloric solution will, according to Dr. Anderson, demonstrate the presence of methylamine, propylamine, butylamine, and amylamine. The following table contains the names and physical properties of the bases which are contained in that portion of the basic oil which distils above 212°. The amylamine, and even the propylamine, can be separated from the basic oils by fractional distillation, instead of the fractional crystallization of platinum salts, but the latter involves less labor.

**Table of the Physical Properties of the Pyridine Series of Bases.**

<table>
<thead>
<tr>
<th>Base</th>
<th>Formula</th>
<th>Boiling Point</th>
<th>Density at 32°</th>
<th>Vapor Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyridine</td>
<td>C₆H₅N</td>
<td>242°</td>
<td>0.9658</td>
<td>2.916</td>
</tr>
<tr>
<td>Picoline</td>
<td>C₆H₄N</td>
<td>275°</td>
<td>0.9613</td>
<td>2.320</td>
</tr>
<tr>
<td>Lutidine</td>
<td>C₆H₄N</td>
<td>310°</td>
<td>0.9467</td>
<td>2.839</td>
</tr>
<tr>
<td>Collidine</td>
<td>C₆H₆N₂</td>
<td>356°</td>
<td>0.9439</td>
<td>4.137</td>
</tr>
</tbody>
</table>

Bone oil will not become very valuable as a naphtha for general purposes until some cheap method of removing its odor has been discovered. The *Oleum animale dipellii* of the older chemists and pharmacists was prepared by distilling bones; it was very similar in properties to bone oil.—C. G. W.

**NAPHTHA FROM CAOUTCHOUC.** *Syn.* Caoutchouc ; Caoutchouc. Caoutchouc, by destructive distillation, yields several hydrocarbons, the accounts of which are contradictory. By repeated rectifications they may be separated into fluids of steady boiling points. The late Dr. Gregory succeeded in obtaining a fluid hydrocarbon from caoutchouc which distilled at 96°, but when treated with sulphuric acid, and the fluid separated by means of water, another hydrocarbon was obtained boiling at 428°. It is most probable, however, that the true composition of caoutchouc has not yet been made out. This will appear by consulting the analyses yet made, many of them indicating too low a hydrogen for the C₆H₄ series, and more nearly approximating to n (CH). The author of this article is engaged in a new examination of these hydrocarbons. It is quite plain, however, that caoutchouc is, in every sense of the term, a naphtha. Caoutchouc is one of the best solvents known for India-rubber.—C. G. W.

**NAPHTHA, COAL.** Ordinary coal naphtha is procured by the distillation of coal tar. The latter is placed in large iron stills, holding from 800 to 1,500 gallons, and distilled by direct steam. As soon as specific gravity of the distillate rises to 0.910, the naphtha is pumped into another still, and distilled with direct steam until the distillate again becomes of the density 0.910. It then constitutes what is termed "rough naphtha."
The residue obtained in the first distillation is run off into cisterns or tar ponds to allow of the removal of the water. This residue is called boiled tar. Pitch oil may be obtained from it by distillation with the naked fire, every 1,000 gallons will yield about 220 gallons of pitch oil. The residue of pitch in the still is run out while in a molten state. The rough coal naphtha contains a great number of impurities of various kinds, the principal cause of the foul odor being the organic bases described in the article NAPHTHA, BASE. To remove these the naphtha is transferred to large cylindrical vessels lined with lead. These vessels contain a vertical axis passing down them, supporting blades of wood covered with lead, and pierced with holes. The axis or shaft has, at its upper end, a crank to enable it to be rotated. The naphtha having been run into the vessel, sulphuric acid is added, and the shaft with its blades made to revolve. By this means the naphtha and acid are brought into intimate contact. The whole is then allowed to settle, and the vitriol which has absorbed most of the impurities, and acquired, in consequence, a thick tarry consistence, is run off. This acid treasy matter is known in the works as "sludge." The naphtha floating above the sludge is then treated a second time with acid, if the naphtha be required of good quality. During the process, the naphtha acquires a sharp smell of sulphurous acid, and retains a certain amount of sulphuric acid in solution. The next process is to treat it with a solution of caustic soda to remove these impurities. This may be effected in an apparatus similar to the first. The naphtha, after removal of the caustic liquor, is next run off into a still, and rectified; it then forms the coal naphtha of commerce. The ordinary naphtha of commerce is often very impure, owing to insufficient treatment with oil of vitriol. The author of this article has obtained from one gallon of commercial naphtha as much as one and a half ounces of the intensely odorous picoline, mixed with certain quantities of other bases of the same series, and also traces of aniline.

In describing coal naphtha, we shall not confine ourselves to the description of those substances which come over in distillation between any given temperature, but shall take a cursory review of the nature and properties of most of the substances produced by the distillation of coal tar. It will be unnecessary here to enter into a minute description of the acids existing in coal tar, insomuch as they have already been treated of in the article CARBONIC ACID.

On the basic constituents of coal naphtha.—Coal tar is particularly rich in bases. They are found accompanying all the fluid naphthas and oils, and probably cannot be separated, by distillation alone, from any of the hydrocarbons of coal naphtha except benzole. It is highly remarkable that while coal tar yields all the pyridine series of bases found in bone oil, no traces of the alcohol series have yet been discovered. At the time that the author of this article commenced his experiments on the coal naphtha bases, there were only three known to be present, namely, aniline, chinoline, and picoline. The two former were discovered in coal tar by Rungé, who called them kyanol and leukol. Picoline was discovered by Dr. Anderson, of Glasgow. The discovery was, at the time, of great value, it being the first instance on record of isomerism among volatile bases. The number of isomeric bases now known is very great, and fresh instances are becoming known every day. The following are the bases known to be present in coal tar, with their formulae. They will be found mentioned under their names in this work. The physical properties of the pyridine series are given under NAPHTHA, BASE.

<table>
<thead>
<tr>
<th>Base</th>
<th>Formula</th>
<th>Boiling Point</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyridine</td>
<td>C₄H₅N</td>
<td>177°</td>
<td>0.850 at 60°</td>
</tr>
<tr>
<td>Picoline</td>
<td>C₄H₅N</td>
<td>230°</td>
<td>0.870</td>
</tr>
<tr>
<td>Lutidine</td>
<td>C₄H₅N</td>
<td>230°</td>
<td></td>
</tr>
<tr>
<td>Collidine</td>
<td>C₄H₅N</td>
<td>304°</td>
<td></td>
</tr>
<tr>
<td>Aniline</td>
<td>C₂H₅N</td>
<td>347°</td>
<td>0.861 at 57°</td>
</tr>
<tr>
<td>Pyrol</td>
<td>C₄H₅N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On the hydrocarbons of coal naphtha.—The following are the principal constituents of those coal naphthas the boiling points of which range between 190° and 350°:

The fluid hydrocarbons boiling above this point have not been well studied. Ordinary coal naphtha, in addition to the above hydrocarbons, contains traces of the homologues of olefiant gas, alluded to in the article NAPHTHA, BOGHEAD. All the above-mentioned hydrocarbons may be separated from each other by careful and sufficiently numerous fractional distillations. It is proper before considering them as pure, to shake them up several times with oil of vitriol, and, after well washing first with water,
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and afterwards with an alkaline solution, to dry them very carefully with chloride of calcium or sticks of potash. It will be observed that in the above table the specific gravities of the hydrocarbons are not in harmony; this arises from the fluids upon which the experiments were made not having all been procured from the same source; for it has been found that the same bodies, as procured from different sources, often present small but appreciable differences in odor, density, boiling point, and other physical properties.

The benzole of coal naphtha may almost entirely be separated by distilling in an apparatus first devised for the purpose by Mr. C. B. Mansfield. The annexed figures from my "Handbook of Chemical Manipulation," illustrate the vessels I am in the habit of employing for the purpose. Fig. 464 consists of a copper or tinued iron still, a, holding about two gallons. The flange, b, b, is merely to support the apparatus in the ring of a gas or charcoal furnace, preferably the former. A wide worm, c c, passes through the top of the still into a water-tight cistern, d d. The worm ends in a discharge pipe, e. The latter is to be attached to a common worm-tub containing cold water. The crude benzole, or coal naphtha, is to be placed by means of the opening f into the still, and all the joints of the apparatus being closed, and effectual condensation insured, the fire is to be lit. The naphtha soon begins to boil, but nothing comes over, because the water in d d effects condensation. In a short time, however, the water in d d begins to get warmer, and, as soon as 177° is reached, benzole begins to come over, and is perfectly condensed in a second worm, kept cold by means of water. It is plain that as the fluids of higher boiling points begin to come over, the water in d d will boil, but distillation then ceases entirely. The reason of this is, that nothing can make the head c c hotter than 212°, because of its being surrounded with water. All hydrocarbons that are not volatile at 212° are consequently condensed there, and fall back into a. The benzole distilling over is quite pure enough for all ordinary purposes. It may, if required very pure, be rectified a second time in the same apparatus, taking care that the head does not get hotter than 180° or 190°. If the benzole is wanted absolutely free from its accompanying hydrocarbons, it must be purified by freezing. For this purpose the rectified benzole is to be placed in a thin glass or metal vessel, and surrounded with snow or pounded ice mixed with salt. The whole apparatus is to be surrounded with sawdust and covered with woollen cloths to prevent access of heat. As soon as the benzole is frozen, it is to be placed in a funnel and allowed to drain. The solid mass when thawed is pure benzole. By this mode of proceeding, a considerable quantity of fluid is always accumulated which refuses to freeze and yet boils at the proper temperature for benzole. I have found it to contain a small quantity of the C6H6 series of hydrocarbons (homologous with olefiant gas). Mr. Church states it to contain benzole in a peculiar condition; he calls it para benzole. The presence of the C6H6 series may always be proved by the readiness with which the fluid decolorizes bromine water.

A simpler form of apparatus for rectifying benzole, and one that answers almost as well, is that represented in fig. 465. It will be seen that the worm c c of fig. 464 is replaced by a straight tube. The mode of use is precisely the same.

Where the benzole is to be extracted from coal naphtha on the large scale, the following apparatus will be found convenient:—The boiler a a, (fig. 466) surrounded by a steam jacket, is connected at its upper extremity with a head, b, answering to the worm e in fig. 464. The head plays into the worm tub d; the benzole being conveyed by the exit pipe e to the reservoir or close tank in which it is to be stored. The tube c c c contains water to condense the hydrocarbons which are to be removed from the benzole. In order to save time it is convenient at the commencement of the operation to heat the water in c c c to about 170°; this is effected by means of the steam pipe l l l, which is connected with the boiler f. The steam is admitted to the jacket of the still by means of the pipe p. The steam can be regulated or stopped altogether by means of the stop-cock q. The cock r is to regulate the admission of steam to the vessel c c c. The man-hole is represented at k.
A small cock to allow the condensed water in the jacket to be run off, is seen at i. Unless the naphtha is of the best quality the benzole will be difficult to extract by the heat of the jacket alone. It will then be necessary to send direct steam into a a. When no more benzole comes over, the remaining naphtha is to be run out of the still by the stop-cock a. Although the boiler f is, for the sake of space, represented in the figure as if placed beneath the support of the condenser or worm tub, it should in practice be removed to a considerable distance for fear of the vapor of the hydrocarbon reaching the stoke-hole and causing an explosion. The condenser b may be arranged in the form of a worm like c in fig. 464, but the precaution is scarcely necessary if the chamber at h, (fig. 466) be made sufficiently capacious. The benzole obtained in the above apparatus is, of course, contaminated with toluole; if, however, the rectification be repeated, the water in the chamber e e e not being permitted to become hotter than 180° F., the resulting benzole will be almost pure. One distillation is amply sufficient for the preparation of the commercial article.

A rectifying column somewhat like Coffey's still may also be employed for preparing benzole.

The less volatile naphtha remaining in the still is by no means valueless; it is adapted for almost all the purposes for which ordinary coal naphtha is applicable. By removing the fluid by the tap h, and distilling it in an ordinary still, a very good coal naphtha of a density of about 0.870 will be obtained.

The number of processes and patents which have been published relating to coal naphtha is immense. There is, as a general rule, an extreme sameness in them. Each inventor uses the processes of his predecessors with some slight alteration or modification, and patents them as if involving an important discovery. It is true that, in some few instances, those alterations are very valuable, but the general feeling with which one rises from the perusal of patents connected with coal naphtha is, that there is nothing really new in them. All processes for their purifications consist, essentially, of treatments with strong oil of vitriol followed by alkalies. It is remarkable to observe the difference in the ideas of inventors and operators with regard to the part played by sulphuric acid in the purification of naph-
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thus. It is by no means uncommon to hear the workmen, and even those who have the direction of naphtha works, attribute the dark color which naphthas acquire by contact with oil of vitriol, to the latter "precipitating out the tar." The fact is, that a carefully distilled naphtha does not contain any tar. The dark color is chiefly due to the removal of the hydrocarbons homologous with olefiant gas. All bodies belonging to this series dissolve with a red color in sulphuric acid, and the fluid on keeping soon begins to evolve sulphurous acid and turn dark, sometimes nearly black. If the naphtha has been insufficiently rectified, it will contain naphthaline, and this will readily unite with the sulphuric acid to form a conjugate acid of dark color.

It is extremely curious that naphthas which contain large quantities of naphthaline will often distil without the latter crystallizing out. It is volatilized in the vapor of the naphtha, and therefore escapes observation. But if a little chlorine be poured into the fluid, or if a little chloride of lime be added, followed by an acid, and the fluid be then distilled, the naphthaline will come over in the solid state, so that it can be removed by mechanical methods. It does not appear to be due to the formation of Laurent's chloride of naphthaline, for the product only contains traces of chloride.

Benzole has been much used of late to remove greasy and fatty matters from cotton, wool, silk, and mixed fabrics. It is by no means essential that the benzole should be absolutely pure for this purpose. By this it is meant that the presence of naphthas boiling somewhat above 177° does not materially affect the usefulness of the fluid. If, however, the naphtha is to be employed for removing greasy stains from dresses, gloves, or other articles to be worn, the purer and more volatile the hydrocarbon, the more readily and completely the odor will be removed by evaporation. Mr. F. C. Calvert has patented the application of benzole to some purposes of this kind. He first purifies the naphtha by means of sulphuric acid and caustic alkalies in the usual manner, and then rectifies it at a temperature not exceeding 212°.

For this purpose the apparatus described in p. 466 will be found well suited. The inventor applies the rectified coal naphtha, or nearly pure benzole, to the following purposes:—1st, for removing spots and stains of grease, i.e. fatty or oily matters, tar, paint, wax, or resin, from cotton, woolen, silk, and other fabrics, when, in consequence of its volatility, no mark or permanent odor remains; 2d, for removing fatty or oily matters from hair, furs, feathers, and wool; and for cleaning gloves and other articles made of leather, hair, fur, and wool; 3d, for removing the fatty matters which exist naturally in wool; 4th, for removing, from wool, tar, paint, oil, grease, and similar substances used by farmers for marking, salving, and smearing their sheep; 5th, for cleansing or removing the oily or fatty matters which are contained in cotton waste that has been used for cleansing or wiping machinery, or other articles to which oil or grease has been applied. In order to remove the above matters by means of coal naphtha, the articles, if small, are merely rubbed with it. On the large scale the matters to be operated on are placed in suitable vessels, and the naphtha is run in. After contact for some hours the fluid is run off, and the fabrics are passed through squeezers and submitted to strong pressure to remove the greater portion of the benzole or naphtha. The naphthas which run out are distilled off, so that the greasy matters may be preserved and used for lubricating machinery or other purposes.

Furniture paste may also be made from light coal naphtha or benzole by the following process:—One part of wax and one of resin is to be dissolved in two parts of the hydrocarbon, with the aid of heat. When entirely dissolved the whole is allowed to cool, and is then fit for use.

It is a vexatious circumstance that no important practical use has been found for naphthaline. It is true that it is used for the preparation of lampblack, but the quantity employed for that purpose is but small. The quantity annually produced by the various gas-works is enormous. Its odor and volatility prevent its being applied to lubricating purposes. It often happens that much valuable time is lost by unscientific operators in endeavoring to remove the smell from such substances as naphthaline; they forget that the odor of a body of this class is a part of itself, and cannot be removed without its destruction. It is possible that the compounds of naphthaline may one day be applied to useful purposes. By treating naphthaline with excess of chlorine, and removing fluid substances with ether, a crystalline paste is obtained. This paste, dissolved in boiling benzole and allowed to repose, deposits beautiful rhombohedral crystals, often of large size. They have exactly the form of Iceland spar, and, like that substance, possess the power of double refraction. When nitronaphthaline is treated with acetic acid and iron filings in the same manner as that employed by M. Béchamp for the production of aniline, a base is obtained of the formula C₂H₇N; it is called naphthalamine. It is, therefore, isomeric with cryptidine, but has no other point of resemblance.

The relation which appears to exist between naphthaline and alizarine is also very interesting, and suggestive of the idea that the former substance will not always be regarded as useless.

It is said that naphthaline has been employed with advantage in the treatment of
NAPHTHA.

psoriasis. M. Emery states that it succeeded in twelve out of fourteen cases. In the two where it failed, the one patient was a woman thirty years of age, who had been afflicted for eight years with psoriasis gyrata; the other patient was a young man who had suffered for several years with lepra vulgaris. In the latter case, two months' treatment having effected no good, pitch ointment was substituted, which effected a cure in two months. The naphthaline was employed in the form of ointment in the strength of 3 per cent. of hard. The application is sometimes, however, attended with severe inflammation of the skin, which must be relieved with poultices. (L’Expérience, Oct. 6, 1845.)

The dead oils, as the less volatile parts of coal tar are called, contain several substances, the nature of which is very imperfectly known. Among them may be mentioned pyrène and chrysène. The former has only been examined by Laurent, who gives the formula \( C_{38}H_{12} \) for it. They are found in the very last portions that pass through the distillation of coal tar. They are also said to be produced during the distillation of fatty or resinous substances. The portions which distil last are in the form of a reddish or yellowish paste, which rapidly darkens in color on exposure to light. Ether separates it into two portions, one soluble, containing the pyrène, the other insoluble containing the chrysène. The pyrène may be obtained by exposing the etiolar solution to a very slow temperature, which will cause it to crystallize out. The composition of pyrène is, according to Laurent,

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>C³⁸</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H²</td>
</tr>
</tbody>
</table>

The portion insoluble in ether consists of chrysène in a tolerably pure state. I have found that it crystallizes on cooling from a solution in Boghead naphtha, in magnificent yellow plates, with a superb lustre resembling crystallized iodide of lead. The following are the results of its analysis. My combustion was made upon chrysène crystallized as above.

<table>
<thead>
<tr>
<th>Laurent</th>
<th>C. G. W.</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>94.82</td>
<td>94.63</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>5.14</td>
<td>5.37</td>
</tr>
</tbody>
</table>

The product given above merely expresses the ratio of the elements; no compound of chrysène has yet been formed which will enable its atomic weight to be determined with certainty. Laurent's analyses were calculated with old atomic weight of carbon.

The heavier coal oils, when exposed to the action of a powerful freezing mixture, often deposit a mass of crystals only partly soluble in alcohol. The soluble portion consists of naphthaline; the other portion, which dissolves with difficulty, is a curious substance, the nature of which is at present not very well known; it has been called anthracène, or paraffin-naphthaline. It appears, from the analyses which have as yet been made, to be isomeric with naphthaline. It fuses at 356°, and boils at about 580°. The density of its vapor, determined at 848°, was 6.741, agreeing very well with the formula \( C_{38}H_{12} \), which requires 6.643. This formula is one and a half times naphthaline, thus: \( C_{38}H_{12} + C_{38}H_{12} = C_{76}H_{24} \).

Metanaphthaline is a peculiar substance which appears to be closely related to the above products. It is formed during the manufacture of resin gas. It is a fatty substance fusing at 138°, and distilling at about 617°; it is at present but little known. A substance which seems to be metanaphthaline has recently been imported in considerable quantity as a lubricating material. It is tinged of a yellow color, probably from the presence of traces of chrysène.

NAPHTHA. NATIVE. In a great number of places in various parts of the world, a more or less fluid inflammable matter exudes. It is known as Persian naphtha, Petroleum, Rock oil, Rangoon tar, Burmese naphtha, &c. These naphthas have been examined by many chemists, but the experiments have been exceedingly defective, and even the analyses most incorrect, for in most cases where a loss of carbon or hydrogen has been experienced, it has been put down as oxygen. The oil procured from the above source, when rectified and well dried, contains no oxygen. The constitution of all of them is probably nearly the same, the odor and physical characters closely agreeing in specimens obtained from widely different sources. A thorough investigation of the most plentiful and well marked of all of these naphthas (namely that from Rangoon) has been undertaken by MM. Warren De la Rue and Hugo Müller, who have been engaged upon it for some years. They find the fluid to consist of two principal series of hydrocarbons, namely the benzole class and another unacted upon by acids, and apparently consisting of the radicals of the alcohols. In addition to the fluid hydrocarbons, Burmese naphtha contains a considerable quantity of paraflne.

Burmese naphtha or Rangoon tar is obtained by sinking wells about 60 feet deep in the soil; the fluid gradually ooze in from the soil, and is removed as soon as the quantity accumulated is sufficient. The crude substance is soft, about the consistence of goose grease, with a greenish brown color, and a peculiar but by no means disagreeable odor. It contains only 4 per cent. of fixed matter. In the distillations, MM. De la Rue and Müller employed super-
heated steam for the higher, and ordinary steam for the lower temperatures. At a temperature of 212°, eleven per cent. of fluid hydrocarbons distil over; they are entirely free from paraffine. Between 230° and 239° F., ten per cent. more fluid distils, containing, however, a very small quantity of paraffine. Between the last-named temperature and 320° F., the distillate is very small in quantity, but from that to the fusing point of lead, 29 per cent. more is obtained. The latter, although containing an appreciable amount of paraffine, remains fluid at 32° F. At this epoch of the distillation, the products begin to solidify on cooling, and 31 per cent. of substance is obtained of sufficient consistency to be submitted to pressure. On raising the heat considerably, 21 per cent. of fluids and paraffine distil over. In the last stage of the operation, 3 per cent. of pitch-like matters are obtained. The residue in the still, consisting of coke containing a little earthy matter, amounts to 4 per cent.

We thus have as the products in this very carefully conducted and instructive distillation,

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Product Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 212°</td>
<td>Free from paraffine</td>
</tr>
<tr>
<td>230° to 239°</td>
<td>A little paraffine</td>
</tr>
<tr>
<td>293° to 320°</td>
<td>Containing paraffine, but still fluid at 320°</td>
</tr>
</tbody>
</table>

At about the fusing point of lead, it is sufficiently solid to be submitted to pressure. The quantity of paraffine diminishes, the pitch-like matters increase, and the coke containing a little earthy impurity is obtained.

All the above distillates are lighter than water. Almost all the paraffine may be extracted from the distillates by exposing them to a freezing mixture. In this manner, no less than between 10 and 11 per cent. of this valuable solid hydrocarbon may be obtained from Burmese naphtha. We may therefore expect a full account of the substances contained in Rangoon tar.—C. G. W.

NAPHTHA, SHALE. The true constitution of shale naphtha, or, as it is sometimes called in commerce "shale oil," has not yet been satisfactorily ascertained. In fact, to do so would involve a very laborious research, or rather series of researches, for the various shales or shists differ much in the quantities and qualities of the naphtha yielded by them. The bituminous shale of Dorsetshire contains much nitrogen and sulphur, arising to a great extent from presence of a large quantity of semi-fossilized animal remains. The crude naphtha, consequently, is intolerably foetid. By repeated treatments with concentrated sulphuric acid and caustic soda it may, however, be rendered very sweet. It then contains pretty nearly the same constituents as Boghead naphtha, i.e., benzole and its homologues, various hydrocarbons of the olefin gas series, and small quantities of the alcohol radicals or isomeric hydrocarbons. There are also present,previous to purification, carbolic acid and numerous alkaloids; but, strange to say, in the samples I examined there was no trace of aniline to be found. There is little doubt that shales of this kind might be most profitably worked by one or other of the recently patented processes for the preparation of photogen and lubricating oil.

French shale oils have been examined by Laurent and Sainte Evre, but the results are not of any very great value, because care was not taken to separate the various series of hydrocarbons from each other. It is true that Laurent fractionally distilled his oil, and Sainte Evre in addition treated his hydrocarbons with sulphuric acid, anhydrous phosphoric acid, and fused potash. These operations would remove basic and acid bodies, and much, if not all, of the homologues of olefin gas, but the residue would contain indefinite mixtures of the benzole and radical series.

Laurent's analyses have been quoted by Gerhardt to show that the hydrocarbons approach in composition the formula \( n(C_2H_4) \). They are as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>( C_{12}H_{24} )</td>
<td>19°</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>( C_{10}H_{16} )</td>
<td>11°</td>
</tr>
</tbody>
</table>

The above analyses are calculated according to the old atomic weight of carbon.

M. Sainte Evre, by determining the vapor densities of the fractions, arrived at the following formula for the hydrocarbons examined by him:

<table>
<thead>
<tr>
<th>Boiling point (°C)</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>275° to 290°</td>
<td>( C_2H_4 )</td>
</tr>
<tr>
<td>255° to 260°</td>
<td>( C_3H_6 )</td>
</tr>
<tr>
<td>215° to 220°</td>
<td>( C_3H_8 )</td>
</tr>
<tr>
<td>132° to 135°</td>
<td>( C_4H_8 )</td>
</tr>
</tbody>
</table>
These results are worth very little except as showing where an excellent field exists for investigation.

Laurent, by treating with boiling concentrated nitric acid that part of shale oil which boiled between 80° and 150° Cent., obtained an acid which he called ampiclic; it is apparently metanmonic with salicylic acid. The same, or more probably a homologous substance, is procured by treating in the same manner the oil boiling between 130° and 160°. Pieric, or, as it is sometimes called, carbazodic acid, is also formed at the same time.

Ampelic acid is a substance about which chemists have felt much curiosity ever since its discovery. It is much to be desired that a new investigation should be made upon it. The following are a few of its properties:—It is white, inodorous, almost insoluble in cold water, and only slightly soluble even when boiling; the solution reddens litmus. It is easily dissolved by alcohol or ether; from solution in those menstrua it is deposited under the form of a crystalline powder. It fuses somewhere about 200° Cent., and distils without alteration.

This last property is a valuable one, as it will enable its vapor density, and consequently its atomic weight, to be easily determined with precision. From its solution in sulphuric acid it is precipitated unaltered by water. Gerhardt gives the following as some of the reactions of this interesting body. The solution of its ammonium salt precipitates chloride of potassium white, the precipitate is soluble in hot water, and crystallizes on cooling. It is not precipitated by solutions of the chlorides of barium, strontium, manganese, or mercury. Acetate of nickel gives a greenish precipitate, acetate of copper greenish blue. Acetate and nitrate of lead gives white precipitates.

The above experiments were made by Laurent in 1887, and, as it is very probable that he never obtained a perfectly pure substance, it is almost certain that valuable and novel results would be obtained on carefully repeating the entire investigation. At the same time, benzolic acid is CH₃CO and ampiclic acid according to its molecular weight. It is more than likely to be a product of oxidation of one of the homologues of benzole.

Intimately connected with the oils of shale are the fluids yielded by the distillation of the numerous bitumens and asphalts found in various parts of the world. Undoubtedly these deposits will one day become of important use in the arts.

The bitumen of Trinidad yields on distillation an intensely foamed oil, and also a very large quantity of water. It also appears to give a considerable quantity of alkalis and ammonia. It will, perhaps, scarcely be a profitable speculation at present to bring this bitumen so far for the purpose of distillation, but doubtless there are many ports into which it could be carried at a reasonable price. It is said that some has already found its way into America, for the purpose of having photogen prepared from it.

France is particularly rich in deposits of bitumen, especially in the volcanic districts of Auvergne, Switzerland, Italy, Germany, Russia, Poland, in fact almost every part of Europe, contains bitumen of various degrees of consistency and value. Even in our own country there are deposits at Alfreton and other places. The Alfreton bitumen is not unlike that of Rangoon.

Bitumens have been examined by various chemists, more especially by Beudant and Vouclod. Their results, however, require to be repeated with great care, as little sufficient attention has not been paid to the purification by chemical means of the various hydrocarbons. Fractional distillation, although absolutely necessary, in order to enable bodies to be obtained of different but specific boiling points, does not do away with the necessity for elaborate purifications by means of bromine, nitric, and sulphuric acids, &c.

There is little doubt that a rigorous examination of the oils procurable by distillation of the various European and other bitumens, would be rewarded, not only by scientific results of great interest, but also by discoveries of immense commercial importance. It must not be forgotten, in connection with the money value of such researches, that the bitumens yield a very high percentage of distillate, much greater than any of the shales or imperfectly fossilized coals which are wrought on the large scale for the preparation of illuminating or lubricating oils.—C. G. W.

NATURE-PRINTING. (Naturseilzdruck, Germ.) The following description of this very beautiful process is an abstract of a lecture delivered by Mr. Henry Bradbury at the Royal Institution:—

Nature-printing is the name given to a technical process for obtaining printed reproductions of plants and other objects upon paper, in a manner so truthful that only a close inspection reveals the fact of their being copies; and so distinctly sensible to even touch are the impressions, that it is difficult to persuade those unacquainted with the manipulation that they are an emanation of the printing-press.

The distinguishing feature of the process consists, firstly, in impressing natural objects—such as plants, mosses, seaweeds and feathers—into plates of metal, causing as it were the objects to engrave themselves by pressure; secondly, in being able to take such casts or copies of the impressed plates as can be printed from at the ordinary copperplate-press.

This secures, in the case of a plant, on the one hand, a perfect representation of its characteristic outline, of some of the other external marks by which it is known, and even
in some measure of its structure, as in the venation of ferns, and the ribs of the leaves of flowering plants; and on the other, affords the means of multiplying copies in a quick and easy manner, at a trifling expense compared with the result—and to an unlimited extent.

The great defect of all pictorial representations of botanical figures has consisted in the inability of art to represent faithfully those minute peculiarities by which natural objects are often best distinguished. Nature-printing has therefore come to the aid of this branch of science in particular, whilst its future development promises facilities for copying other objects of nature, the reproduction of which is not within the province of the human hand to execute; and even if it were possible, it would involve an amount of labor scarcely commensurate with the result.

Possessing the advantages of rapid and economic production, the means of unlimited multiplication, and, above all, unsurpassable resemblance to the original, Nature-printing is calculated to assist much in facilitating not only the first-sight recognition of many objects in natural history, but in supplying the detailed evidences of identification—which must prove of essential value to botanical science in particular.

Experiments to print direct from nature were made as far back as about two hundred and fifty years; it is certain, therefore, that the present success of the art is mainly attributable to the general advance of science, and the perfection to which it has been brought in particular instances.

On account of the great expense attending the production of woodcuts of plants in early times, many naturalists suggested the possibility of making direct use of Nature herself as a copier. In the Book of Art, of Alexis Pedemontanus (printed in the year 1572), and translated into German by Wecker, may be found the first recorded hint as to taking impressions of plants.

At a later period—in the Journal des Voyages, by M. de Moncoys, in 1650, it is mentioned that one Wellenstein, a Dane, gave instruction in making impressions of plants. The process adopted to produce such results at this period consisted in lying out flat and drying the plants. By holding them over the smoke of a candle, or an oil lamp, they became blackened in an equal manner all over; and by being placed between two soft leaves of paper, and being rubbed down with a smoothing bone, the soot was imparted to the paper, and the impression of the veins and fibres was so transferred. But though the plants were dried in every case, it was by no means absolutely necessary; as the author has proved by the simple experiment of applying lampblack or printer’s ink to a fresh leaf, and producing a successful impression.

Linnaeus, in his Philosophia Botanica, relates that in America, in 1707, impressions of plants were made by Hessel; and later (1728-1757), Professor Knipho, at Erfurt (who refers to the experiments of Hessel), in conjunction with the bookseller Fünkhe, established a printing-office for the purpose. He produced a work entitled Herbarium Vivum. The range and extent of his work, twelve folio volumes, containing 1,200 plates, corroborates the curious fact of a printing-office being required. These impressions were obtained by the substitution of printer’s ink for lampblack, and flat pressure for the smoothing-bone; but a new feature at this time was introduced—that of coloring the impressions by hand according to nature—a proceeding, which though certainly contributing to the beauty and fidelity of the effect, yet had the disadvantage of frequently rendering indistinct, and even of some times totally obliterating, the tender structure and finer veins and fibres. Many persons at the time objected to the indistinctness of such representations, and the absence of parts of the fructification; but it was the decided opinion of Linnaeus, that to obtain a representation of the difference of species was sufficient.

In 1748, Seligmann, an engraver at Nuremberg, published in folio plates figures of several leaves he had reduced to skeletons. As he thought it impossible to make drawings sufficiently correct, he took impressions from the leaves in red ink, but no mention is made of the means he adopted. Of the greater part he gave two figures, one of the upper and another of the lower side.

In the year 1763 the process is again referred to in the Gazette Salutaire, in a short article upon a Recette pour copier toutes sortes de plantes sur papier.

About twenty-five or thirty years later, Hoppe edited his Ectypa Plantarum Rario- bonensium, and also his Ectypa Plantarum Selectarum, the illustrations in which were produced in a manner similar to that employed by Knipho. These impressions were found also to be durable, but still were defective.

In the year 1809 mention is made in Prêtell’s “Thesaurus” of a New Method of taking Natural Impressions of Plants; and lastly, in reference to the early history of the subject, the attention of scientific men was called to an article, in a work published by Grazer, in 1814, on a New Impression of Plants.

Twenty years afterwards, the subject had undergone remarkable change, not only in the results produced, but also in the mode of operation to be pursued, which consisted in fixing an impression of the prepared plant in a plate of metal by pressure. It also appears, on the authority of Professor Thieele, that Peter Kyli, a Danish goldsmith and engraver,
established at Copenhagen, applied himself for a length of time to the ornamentation of articles in silver ware, and the means he adopted were, taking copies of flat objects of nature and art in plates of metal by means of two steel rollers. Here may be marked the first real steps of the process, from a simple contrivance to an art. The subsequent development, which science has given to these means, and the amplifications which experience has added, have realized what can now be produced; but it should not be assumed that adaptation and amplification are invention.

Various productions in silver, of Kyhl's process, were exposed in the Exhibition of Industry held at Charlottenburg, in May, 1833. In a manuscript, written by this Danish goldsmith, entitled The Description (with forty-six plates) of the Method to copy Flat Objects of Nature and Art, dated 1st May, 1833, is suggested the idea of applying this invention to the advancement of science in general. The plates accompanying this description represented printed copies of leaves, of linen and woven stuffs, of laces, of feathers of birds, scales of fishes, and even of serpent-skins.

It would appear that Peter Kyhl was no novice at the process. He distinctly points out what he conceives to be its value, by the subjects that he tried to copy, and he enters into detail as to the precautions to be observed in the operation of impressing metal plates so as to insure successful impressions. His manuscript explains that he had experimented with plates of copper, zinc, tin, and lead. Still there existed obstacles which prevented him from making any application of his invention. In the case of zinc, tin, and copper plates, the plant, from the extreme hardness of the metals, was too much distorted and crushed; while in lead, though the impression was as perfect as could be, there were no means of printing many copies; as it was not possible, after the application of printer's ink, to retain the polished surface that had been imparted to the leaden plate, or to cleanse it so thoroughly as to allow the printer to take impressions free from dirty stains. This was a serious obstacle, which was not compensated for even by the peculiarly rich surface of the parts that were impressed, attributable to the lead being more granular than copper. The effect, which is so favorable to adding density or body of color, without obliterating the veins and fibers. Peter Kyhl died in the same year that he made known his invention. At his death, his manuscripts and drawings were deposited in the archives of the Imperial Academy of Copenhagen.

To proceed to more modern efforts. Dr. Branson, of Sheffield, in 1847, commenced a series of experiments, an interesting paper upon which was read before the Society of Arts in 1851, and thereby, for the first time, was suggested the application of that second and most important element in Nature-printing, which is now its essential feature—the ELECTROTYPY.

It then occurred to Dr. Branson that an Electrotype copy would obviate the difficulty.

He afterwards stated that he abandoned the process of Electrotypy in consequence of his finding it tedious, troublesome, and costly to produce large plates. Having occasion, however, to get an article cast in brass, he was astonished at the beautiful manner in which the form of the model was reproduced in the metal. He determined, therefore, to have a cast taken in brass from a gutta-percha mould of ferns, and it was much gratified to see the impression rendered almost as minutely as by the Electrotype process; the mode of operation is to place a sheet of fern, algae, or similar flat vegetable form, on a thick piece of glass or polished marble; by softening a piece of gutta-percha of proper size, and placing it on the leaf, it is carefully down; it will receive sharp and accurate impression from the plant. The gutta-percha, allowed to harden by cooling, is then handed to a brass-caster, who reproduces it in metal from its moulding-base.

In 1853, Professor Leydolt, of the Imperial Polytechnic Institute at Vienna, availing himself of the resources of the Imperial Printing-Office, carried into execution a new method he had conceived of representing agates and other quartzose minerals in a manner true to nature. Professor Leydolt had occupied himself for a considerable period in examining the origin and composition of these interesting objects in geology. In the course of his experiments and investigations he had occasion to expose them to the action of hydrochloric acid, when he found in the case of an agate, that many of the concentric rings were totally unchanged, while others, to a great extent decomposed by the acid, appeared as hollows between the unaltered bands. It then occurred to Professor Leydolt that the surfaces of bodies thus corroded might be printed from, and copies multiplied with the greatest facility.

The simplest mode for obtaining printed copies is to take an impression direct from the stone itself. The surface, after having been treated with hydrochloric acid and dried; then carefully blackened with printer's ink. By placing a leaf of paper upon it, and by pressing it down upon every portion of the etched or corroded surface with a burnisher, an impression is obtained, reproducing the crystallized rhombohedral quartz, black, and the weaker parts that have been decomposed by the action of the acid, white. It requires but a small quantity of ink, and particular care must be exercised in the rubbing down of the impression. This mode is good as far as it goes—but it is slow and uncertain—and means a certain amount of risk, owing to the brittle nature of the object; and the effect produced is not altogether correct, since it represents those portions black that should be white, and those white that should be black.
The stone not being sufficiently strong to be subjected to the action of a printing-press, an exact fac-simile cast, therefore, of it must be obtained, and in such a form as can be printed from. To effect this, the surface of any such stone (previously treated with fluorine acid) must be extended by embedding it in any plastic composition that will yield a flat and polished surface, so that the composition surrounding the corroded stone will be level with its surface; all that is necessary now is to prepare the whole surface for the electrotype apparatus, by which a perfect fac-simile is produced, representing the agate impressed, as it were, into a polished plate of copper. This forms the printing plate. The ink in this case, as opposed to the mode before referred to, is not applied upon the surface, but in the depressions caused by the action of the acid on the weaker parts; the paper is forced into these depressions in the operation of printing, which results in producing an impression in relief.

Mr. R. F. Sturges, of Birmingham, states that in August, 1851, he was engaged in making certain experiments with steel rollers and metal plates for ornamenting metallic surfaces, for which he obtained a patent sealed in January, 1852. He produced plates in lead, tin, brass, and steel from various fabrics, such as wire lace, thread lace, perforated paper, and even from steel engravings, particularly a medallion of the Queen, from which impressions were printed, and which were distributed among his friends—but that which he did, led to no such result as we are at present considering, and nothing more was heard of the subject until the publication of Nature-printing in its present state. He, however, also considers himself the undoubted inventor of Nature-printing, notwithstanding what has been done by the experiment of Kyhl in 1853.

Mr. Aitken too, about this period was occupied in making experiments for the ornamentation of Britannia metal, and also claims the invention, having introduced the use of natural objects, and, as he says, expressly for printing purposes. But Sturges and Aitken only followed Kyhl in their operations, as the one experimented with steel rollers for the purpose of ornamenting metallic surfaces, while the other applied the same to printing purposes, both of which experiments were carried out by Kyhl.

In the Imperial Printing-Office at Vienna, the first application of taking impressions of lace on plates of metal, by means of rollers, took place in the month of May, 1852; according to Councillor Auer's statement in his pamphlet, it originated in the Minister of the Interior, Ritter von Baumgartner, having received specimens from London, which so much attracted the attention of the Chief Director, that he determined to produce others like them. This led to the use of gutta-percha after the manner that Dr. Branson had used it; but finding this material did not possess altogether the necessary properties, the experience of Andrew Worrin induced him to substitute lead, which was attended with remarkable success. This was, however, only following in the steps of Kyhl. Professor Haidinger, on seeing specimens of these laces, and learning the means by which they had been obtained, proposed the application of the process to plants.

The substitution of lead for gutta-percha was a great step in the process, but would have been insufficient had not the requisite means already existed for producing faithful copies of those delicate fibrous details that were furnished in the examples of botanical and other figures in metal. These means consisted mainly in the great perfection to which the precipitation of metals upon moulds or matrices by electro-galvanic agencies has been brought, the application of which—more generally known by the name of the Electrotype process—was suggested and executed by Dr. Branson in 1851; still he met with no signal success, which may be attributed to his experiments having been conducted on a limited scale.

The first practical application of nature-printing for illustrating a botanical work, and has been attended with considerable success, is to be found in Chevalier Von Heisler's work on the mosses collected from the valley of Arpaseh, in Transylvania; the second (first in this country), is a work on the "Ferns of Great Britain and Ireland," by Thomas Moore, in the course of publication, under the editorship of Dr. Lindley. Ferns, by their peculiar structure and general flatness, are especially adapted to develop the capabilities of the process,—and there is no race of plants where minute accuracy in delineation is of more vital importance than in that of the ferns; in the distinction of which, the form of indentations, general outline, the exact manner in which repeated subdivision is effected, and especially the distribution of veins scarcely visible to the naked eye, play the most important part. To express such facts with the necessary accuracy, the art of photography would have been insufficient, until Nature-printing was brought to its present state of perfection.

The beautiful productions which have been given to the public by Mr. Henry Bawbry sufficiently prove the applicability of the processes which we have described. The coloring of the plates has been greatly improved by practice, and by the deposition of nickel on the surface of the electrotype plate the printer has been enabled to print off thousands of impressions without any evidence of deterioration.

NICOTINE. This alkaloid is the active principle of the tobacco plant; it was first obtained, in an impure state, by Vauquelin in 1809. It is contained in the different species of tobacco, probably in the state of malate or citrate. It was obtained pure by Possel and
NICOTINE.

Reimann from the leaves of the Nicotiana Tabacum, Macrophylia rustica, and Macrophylia glatiosa. Nicotine and its salts have been examined and analyzed by M. Ortliege, Barral, Melsen, and Schlessing.

The following is the process employed by M. Schlessing for extracting the nicotine from the tobacco. The tobacco leaves are exhausted by boiling water, the extract is then evaporated till solid, or to a syrupy consistence, and shaken with twice its volume of alcohol. Two layers are formed, the upper layer is black and almost solid, and contains some malate of lime, the upper layer containing all the nicotine. This latter is concentrated by distillation, and again treated with alcohol to precipitate certain substances. The solution is concentrated, and treated with a concentrated solution of potash; it is allowed to cool, and is then agitated with ether, which dissolves all the nicotine. To the ethereal solution is added powdered oxalic acid, when oxalate of nicotine is precipitated as a syrupy mass. This is washed with ether, treated with potash, taken up with water, and distilled in a salt bath, when the nicotine comes over, and may be rendered pure and colorless by re-distilling in a current of hydrogen.

The following are the quantities contained in the various American tobaccos, according to M. Schlessing:

<table>
<thead>
<tr>
<th>Tobacco</th>
<th>Nicotine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia</td>
<td>6.87</td>
</tr>
<tr>
<td>Kentucky</td>
<td>6.09</td>
</tr>
<tr>
<td>Maryland</td>
<td>2.29</td>
</tr>
<tr>
<td>Havana</td>
<td>2.90</td>
</tr>
</tbody>
</table>

M. Melsen has observed the presence of nicotine in the condensed products of tobacco smoke. The oil which is formed in pipes after smoking tobacco in them, and which gives color to the pipe, contains nicotine. The question may then perhaps be asked, "If tobacco smoke contains such a deadly poison, why are there not more ill effects from smoking?"

It may perhaps be answered in this way: tobacco when smoked only yields about 1/150th or less, of its weight of nicotine, and then very little of that is condensed in the mouth. And again, the system may become accustomed to it, as is the case with opium enters, and then it requires much more to take an effect; it can scarcely be doubted, though, that the continual habit of smoking large quantities of tobacco is injurious.

Nicotine when pure is a colorless, transparent, oily liquid, possessing an acrid odor and an acrid, burning taste. Its density is 1.024, and that of its vapor 5·607. It restores the blue color of reddened limus, and renders turmeric brown. It becomes yellowish by age, and when exposed to the air becomes brown and thick, absorbing oxygen. It is very soluble in water, alcohol, and the oils (fixed and volatile); also in ether, which has the power of extracting it completely from its aqueous solution.

It is very hygrosematic; exposed to a moist atmosphere, it rapidly absorbs water, but loses it again in an atmosphere dried by potash. When thus hydrated it becomes a solid crystalline mass if exposed to the cold of a mixture of ice and salt. When anhydrous it does not become solid at 14° F. It boils at 482° F., and is at the same time slightly decomposed; but notwithstanding its high boiling point, it may be easily distilled with the vapor of water without decomposition.

The vapor of nicotine is so irritating that we should experience a difficulty of breathing in a room where a drop of that alkaloid had been volatilized. Its vapor burns with a white smoky flame, depositing charcoals, like an essential oil. Nicotine turns the plane of polarization strongly to the left. From the volume of its vapor, and from the quantity of sulphuric acid required to form with it a neutral salt, the formula of nicotine would appear to be C_{10}H_{14}N_{2}, but from some of its combinations it would appear to be half of this, viz., C_{6}H_{1}N, and is so written by some chemists.

By the aid of heat nicotine dissolves sulphur, but not phosphorus. Nicotine unites with acids, forming salts, which are very deliquescent, difficultly crystallizable, insoluble in ether, except the acetate, and when pure possess no smell, but an acrid tobacco taste. The double salts which nicotine forms are crystalline much more easily.

The aqueous solution of nicotine is colorless, transparent, and strongly alkaline; it forms a white precipitate in a solution of corrosive sublimates, also in a solution of acetate of lead, and with both chlorides of tin. The precipitate which it forms with solutions of the salts of zinc is soluble in an excess of nicotine. Salts of copper give with it at first blue precipitates, but these dissolve in excess of nicotine, forming a deep blue solution, as they do when supersaturated with ammonia. Bichloride of platinum yields with it a yellow granular precipitate. A solution of permaugminate of potash is immediately decolorized by a solution of nicotine.

Pure concentrated sulphuric acid turns nicotine red, in the cold, and by the application of heat the liquid becomes thick and darker, and when boiled with it, becomes black, and gives off sulphurous acid. With cold hydrochloric acid it gives off white fumes, just as ammonia does; when heated, the mixture becomes more or less violet-colored.
NITROGEN. 801

Nitric acid communicates to it, by a gentle heat, an orange yellow color, with disengagement of red vapors which become deeper as the temperature is raised, until after prolonged distillation nothing but a black mass remains. Chlorine acts very strongly on it, disengaging hydrochloric acid and yielding a blood-red liquid.

Iodine water precipitates it of a brown color.

Nitric acid is a most powerful poison, one drop put on the tongue of a large dog being sufficient to kill it in two or three minutes.

The quantity of nicotine contained in any sample of tobacco, may be determined as follows: about 150 grains of tobacco is exhausted, in a continuous distillation apparatus, by means of ammoniated ether; after driving off the ether and ammonia by heat, the quantity of nicotine may be determined by a standard solution of sulphuric acid; 300 pts. of sulphuric acid (subhydrous SO₃), neutralizing 2,025 pts. of nicotine (Schlessing).—H. K. B.

NITROBENZOLE (Azobenzole). C₆H₄(NO₂). It is important in the arts, both as a source of aniline for the manufacture of dye-colors, and on account of its use for flavoring as a substitute for oil of bitter almonds, which it closely resembles in flavor when pure, and over which it has the advantage of not being poisonous.

It is prepared from benzole (which see), by adding it drop by drop to hot fuming nitric acid; the nitrobenzole separates on dilution with water in the form of a yellowish oil, and may be purified by washing with water alone, or a solution of carbonate of soda. It has a density of 1.209, at 60 F. (15.5 C.), and just above the freezing point of water is converted into a crystalline solid.

It is nearly insoluble in water, but alcohol and other dissolve it in all proportions.

Its conversion into aniline under the influence of reducing agents has been before mentioned. See aniline.

Nitrobenzole may be viewed as having been derived from benzole C₆H₅, by the substitution of one equivalent of hydrogen by the tetroxide of nitrogen, thus:

C₆H₅NO₆

H. M. W.

NITROGEN. Determination of its purity.—The simplest and most accurate process is that of M. Bunsen. The first thing is to determine whether a combustible gas containing oxygen be present. For this purpose it is merely necessary to pass an electric spark through the gas contained in a eudiometer. If the bulk remains unaltered, the absence of any considerable amount of combustible gas mixed with oxygen is proved. But they may be present in such small quantity, as compared with the noncombustible gas, that no explosion can ensue on passing the sparks. It is then necessary to add some battery gas in order to render the mixture inflammable. [By "battery gas" is understood the gas obtained by the electrolysis of water.] For the purpose of the experiment we may add to every 100 volumes of the gas under examination 40 volumes of battery gas. If the volume after explosion be unaltered, the total absence of oxygen and combustible gases is demonstrated. It is still possible that the nitrogen may be contaminated with oxygen, although inflammable gases are absent. To determine this fact we must add both hydrogen and battery gas in such proportions that the volume of the original gas plus hydrogen is to that of the battery gas as 100 : 40. If no oxygen be present the volume after explosion will be that of the original gas and the hydrogen. The reason being that if oxygen had been present some of the hydrogen would have disappeared in order to form water. The nitrogen gas may still be contaminated by a trace of a combustible gas. To determine this point, as much common air is to be added to the last mixture containing hydrogen, as will form a detonating mixture with that hydrogen. This detonating mixture so produced should form from 26 to 64 per cent. of the incombustible gases. If, on making the explosion, it is found that two-thirds of the condensation is equal to the volume of the hydrogen added, it will show that no combustible gas was present, and that, therefore, the original gas consisted of pure nitrogen.

Special affinities of nitrogen.—In the same manner that ordinary metallic substances absorb oxygen with avidity from the atmosphere, especially at more or less elevated temperatures, so other elementary bodies combine with nitrogen to form the nitrates. Messrs. Wohler and Sainte-Claire Deville have carefully investigated this subject, and with great success. When a mixture of tunicic acid and charcoal is heated in a charcoal tube, at the temperature sufficient to fuse platinum, and a current of dry nitrogen is sent over the mixture, the gas is absorbed with such rapidity that, no matter how rapid the current, none escapes from the tube.

Boron also possesses great tendency to combine with nitrogen at high temperatures. Amorphous boron heated in a current of ammonia becomes incandescent, the nitrogen is absorbed and the hydrogen escapes, and may be inflamed at the exit of the apparatus. A mixture of boracic acid and charcoal, if ignited in a current of nitrogen, yields the white infusible nitre of boron, first described by Mr. Balmain under the name of Ethogen, but subsequently more accurately investigated by M. Wohler.

Silicon also combines with nitrogen under favorable circumstances. These facts, coupled
NITRO-GLUCOSE.

with the old experiment made by the French chemists on the nitrate of potassium and the action of ammonia at a red heat upon iron, show that nitrogen is far from being the inert substance generally supposed. — C. G. W.

NITRO-GLUCOSE. When we act on finely powdered cane sugar with nitro-sulphuric acid, a pasty mass is first formed; if this be stirred for a few minutes lumps separate from the liquid. When these lumps are kaeaded in water until every trace of acidity is removed, they acquire a white and silky lustre; these are the above-named substance.

NITRO-MURIATIC ACID; *Aqua regia* (*Acide nitro-muriatique*, Fr.; *Salpetre-salzvere, Königswasser*, Germ.) is the compound menstruum invented by the alchemists for dissolving gold. If strong nitric acid, orange-colored by saturation with nitrous or hyponitric acid, be mixed with the strongest liquid hydrochloric acid, no other effect is produced than might be expected from the action of nitrous acid of the same strength upon an equal quantity of water; nor has the mixed acid so formed any power of acting upon gold or platinum.

But if colorless concentrated nitric acid and ordinary hydrochloric acid be mixed together, the mixture immediately becomes yellow, and acquires the power of dissolving these two noble metals. Mr. E. Davy seems first to have obtained a gaseous compound of chlorine and binoxide of nitrogen in 1859, and a combination of these two constituents was distilled from *aqua regia*, and liquefied by M. Baudrimont in 1858. But it was not until M. Gay-Lussac investigated the subject (Annales de Chimie, 3me, sér. xxi. 203; or Chemical Gazette, 1846, p. 289) that the true nature of the mutual action of nitric and hydrochloric acids was fully explained. When these two acids are mixed in a concentrated state, a reaction soon commences, the liquid becomes red, and effervescence takes place, from the escape of chlorine and a chloronitric vapor. On passing this gaseous mixture through a U tube, the bent part of which is immersed in a freezing mixture of ice and salt, the chloronitric compound is condensed as a dark-colored liquid, and is thus separated from the chlorine which accompanied it.

Chloro-nitric acid, NOCl, may be represented as a peroxide of nitrogen, in which two equivalents of oxygen are replaced by two equivalents of chlorine. This chloro-nitric acid does not take any part in the dissolving of gold and platinum, which is effected by the chlorine alone.

Chloro-nitric acid may also be formed by mixing the two gases, binoxide of nitrogen and chlorine, in equal volumes, which assume a brilliant orange color, and suffer a condensation of exactly one-third of their original volume. Another compound of chlorine and binoxide of nitrogen always appears simultaneously with this in variable proportions. Its composition is NOCl, and may be represented as nitrous acid (NO₂), in which one equivalent of oxygen has been replaced by one of chlorine. It is a vaporose liquid, possessing similar properties to the other, but having a much greater vapor density.

The theoretical vapor density of the chloro-nitric acid is 1.74, and that of the chloronitrous acid 2.259.

The vapors of both these compounds are decomposed, when conducted into water, into hydrochloric acid and hyponitric or nitrous acid. They are also decomposed by mercury; the chlorine combining with the metal, leaving pure binoxide of nitrogen.

Various proportions of nitric and hydrochloric acids are used in making aqua regia; sometimes two or three parts, and sometimes six parts of hydrochloric acid to one part of nitric acid, and occasionally chloride of ammonium, instead of hydrochloric acid, is added to nitric acid for particular purposes, as for making a solution of tin for the dyers. An aqua regia may also be prepared by dissolving nitric in hydrochloric acid.—H. K. B.

NITROUS ACID (NO₂; equivalent, 38), is obtained by mixing four measures of binoxide of nitrogen with one measure of oxygen; they unite and form an orange-red vapor, which when exposed to a temperature of 0° Fahr. condenses to a thin mobile green liquid. It is decomposed by water, and is converted into nitric acid and binoxide of nitrogen.

3NO₂⁺ HO = HNO₃⁺ 2NO₂

On this account it cannot be made to unite directly with metallic oxides; the salts of this acid are therefore obtained by an indirect process. Nitrate of Potash, when exposed to a high temperature, is decomposed, losing oxygen and becoming nitrate of potash; some caustic potash is also formed at the same time. To obtain it pure, this is dissolved in water, and while boiling we add nitrate of silver, when we obtain first of all a dark precipitate of oxide of silver, caused by the caustic potash; which is separated by a filter, and on cooling the liquid the nitrate of silver crystallizes in white needles, which may be purified by recrystallization. From this salt the pure nitrates may be obtained; for instance, by adding to a solution of nitrate of silver chloride of potassium, we obtain the potash salt,

AgNO₃ + KCl = AgCl + KNO₃

HYPONITRIC ACID (NO₂; equivalent 46) is best procured by distilling, in a coated glass retort, perfectly dry nitrate of lead. Hyponitric acid and oxygen pass over into a receiver, surrounded with a freezing mixture; the former condenses into a liquid, while the oxygen passes off by the safety tube, and only oxide of lead remains in the retort. This hyponitric acid or peroxide of nitrogens is a liquid, colorless at —4° Fahr., but is at higher temperatures
yellow and orange. It boils at 82° Fahr., giving off a dark red vapor, which becomes almost black when further heated. A beautiful lead-salt of this acid has been discovered by M. Peligot. It is formed by digesting a dilute solution of nitrate of lead with finely divided metallic lead at a temperature between 150° and 170° Fahr. See Ure's Chemical Dictionary.—H. K. B.

NUTRITION, or the process for promoting the growth of living beings, occupies a most important position in the study of physiology, and in the important practical question of health. In some of the more succulent plants we observe that they increase in volume after detachment from their parent soil, by the absorption of the nutrient which they find in the atmosphere, viz., oxygen, vapor of water, carbonic acid, and ammonia. But all these are gaseous bodies or vapors, while the plant itself is a solid. Hence we infer that such a plant is capable of reducing gases to a solid form, and of thus increasing in bulk and weight. It appears that all plants are similarly endowed, and that they mainly subsist by feeding on the gases which surround them, by converting those elastic fluids, assisted by the elements of the soil, by means of the organs with which they are supplied, into the solid forms of the vegetable kingdom, so endless in figure, but yet so lovely that the greatest familiarity only renders them objects of superior admiration. When we turn to the animal world we find that the individuals of which it is composed are incapable of condensing gases. The least educated person knows that animals cannot subsist on air, but that they require to imbibe solid matter, which, by research, it has been found must be similar to that of which they themselves consist. Hence an animal may be defined to be a being which subsists by appropriating to itself food similar to the matter of which its own body is composed. A reasoning thus found for its locomotion; while a plant finding its nourishment in the air in which it is immersed, has its food brought to it by the usual laws of inanimate nature. In some of the lower parts of the animal scale it has been found that matter exists (cellulose) identical with that supposed to be peculiar to vegetables, and hence it may be probable, that, as nature is simple in her works, the animated world consists of a chain, formed of a series of beings, passing down in regular gradation, from comparatively the most perfect to the most imperfect state; the lowest plant being closely allied to the lowest form of animal. If this be so, it will at once be obvious, that to say where plants begin and animals end, cannot be a problem of easy solution. But even in the higher classes of animals, substances usually considered characteristic of vegetable life have been recently believed to have been detected. But the occurrence of such materials in the animal structure upon a limited scale, might be possibly accounted for by processes of reduction, so peculiarly the distinguishing feature of the chemistry of animals, rather than by constructive means, such as denotes the result of vegetable activity.

The determination of the proper food for animals is a great experiment, and must be guided by the light of science. In reference to the human race, we must carefully study the habits and the results of the instinct of the inferior animals subsisting on similar aliment. For it is evident that there are certain laws which naturally regulate the lower beings in the choice of their food. It would be a phenomenon to hear of the suicide or accidental death, from choice of food, of a domesticated animal, still more so, of that of a creature which is free to roam amid the wild scenes of nature. We can recall but an isolated case of the failure of animal instinct with regard to the selection of food. It was in the instance of a pony which swallowed a quarter of an ounce of dried and powdered monkshood (Aconitum napellus). The animal suffered considerably, as if under an attack of glanders, for a few hours. But these occurrences are so rare that it might almost be affirmed that man is the only created being which disobeys the laws of nature. It is merely when domesticated, and under circumstances analogous to those in which man himself is placed, that we find the inferior creation imitating, by such experiments, the example of their more godlike superiors.

The consideration of the subject of nutrition comprehends the nature of nutriment or food, and of its change into blood, and into the solids and fluids of the animal structure. Food is required in proportion to the wear and tear of the body. The waste which the animal system thus undergoes varies with the age and the labor to which the animal is subjected. Hippocrates knew that children are more affected by abstinence than young persons, these more than the middle-aged, and the latter more than old men. In conformity with this observation, Dante has framed the stirring incidents in the story of Count Ugolino, a nobleman of Pisa, who was confined, with his four sons, in the dungeon of a tower, the key of which being cast into the river Arno, they were, in this horrible situation, starved to death. On the fourth morning, the youngest child "sank in death," while the others followed "one by one." From the history of the slave traffic we learn that many of the poor Africans, torn from their country and friends, often prefer death in various forms to a life of bondage. Some of them have been known to starve themselves to death; and in two cases, in which the details are graphically supplied, the pains of the sufferer were terminated "in eight or ten days," while in the other case the mortal scene was closed on the ninth day. (Dr. Trotter, Mr. Wilson, 1790, Parl. Ann. Conn.) An interesting incident.
NUTRITION.

has been recorded of a North American Indian, the last of his tribe, which had been thus almost extinguished by small-pox. He resolved to die; and, abstaining from all nutriment, perished on the ninth day. (Cattlin.) In order to study the nature of the process of nutrition, we are obliged to take advantage of an unusual opportunity, in viewing the animal system. One of the readiest means seems to be, to ascertain how, without the use of food, the built-up animal loses weight, languishes, and dies, under the conditions of maimon; and for this purpose we have too frequent opportunities among the children of the poor in ill-ventilated, lowly dwellings; or we may experiment upon an inferior animal, ascertain daily its loss of weight by absence of nutriment, and after the lapse of a sufficient period, feed it with aliment carefully analyzed. The great change in the weight occasioned by the passage of the food from the stomach into the circulation, is then to be watched, and the further influence on the system by its disappearance in the form of excretions, and of expiration by the lungs and skin. Death is occasioned in the instances related, by starvation, as it is termed in common language. In other words, the oxygen which a human being is compelled to introduce into his lungs daily, to that extent of 324 ounces, combines with the carbon and hydrogen of the solid tissues of the body, to be expired in the form of carbonic acid. The amount of carbon actually consumed has been found to be 123 1/4 ounces. The consumption of the carbon and hydrogen in each animal must depend on the oxygen introduced by respiration. Hence the child, as in the tragedy of Dante, whose respiratory organs are in great activity, requires a more frequent supply of food, and in greater abundance, than an adult. A bird deprived of food, dies on the third day; while, a serpent—which, when confined in a bell jar of air consumes in an hour so little oxygen that the carbonic acid formed is appreciable—can live without food for three months or longer. (Liebig.) It has been found that turledoves, when kept without solid food for seven days, lost 4 1/2 cent. of their weight, and 2 6/5 cent. of carbon by respiration, having exhales daily 3 9/12 per cent. when fed on millet; the extinction of 1 4/10 cent. of the weight of the body. (Chas. B. sér. 11, 433.) Other researches have shown that mammalia lose daily in starvation 1 2/4 cent., thus affording a mean of 4 2/ cent. of their weight. (Chosat.) A cat, weighing about 90 ounces (2,572 grammes), died on the eighteenth day of starvation, losing daily 2 3/7 cent. of its weight; the total loss being 5 7/ cent. of its weight. (Bidder and Schmidt.) The deductions which have been made from this experiment are that the cat lost 12 9/3 grammes during the first 5 days, 24 2/4 grammes during the second 5 days, which is an average of 4 4/5 grammes daily. In another experiment, a cat weighing 504 7 8 grammes had injected into its stomach daily 150 grammes of water. The trial was continued for a week, during which the animal lost 438 grammes, or 62 57 grammes daily, a less diminution of weight than when no water was supplied; and hence we can understand, in some measure, the facts which have been detailed of prostrated cases of starvation under the influence of water. Of the different parts of the body which relatively sustain diminution of weight in these instances, it appears that the blood undergoes the greatest loss, or about 9 7/1 cent. of its weight during the 18 days, the pancreas 8 1/4 cent. of the fatty tissue 8 9/7 cent., muscles and tendons 6 6/9 cent., brain and spinal cord 3 7/6, bones 1 4/3 cent., kidneys only 6 2/ cent. of each of their original weights. Hence the loss of weight in starvation is chiefly in the muscles, the brain and spinal cord; in the pancreas and kidneys, less than 1/2 cent. That portion of the muscular tissue, a quarter to the fat, and the remaining quarter to all the other organs. It seems to be principally the products of decomposition of the muscles and of the fat which are represented in the excretions. With reference to the form in which these portions of the animal frame disappear from the system in the excretions and exhalations, it appears that the daily loss of muscle undergone by an animal was 0 11 cent. of its weight, while the fat was 4 2/2 cent. These yielded 2 16 cent. of carbonic acid, 1 6 cent. of aqueous vapor through the skin, 20 cent. of urea in the urine, 90 8 cent. of sulphuric acid, 90 1 cent. of phosphoric acid, 90 2 cent. inorganic constituents of the urine, 90 8 cent. of dry feces (including 92 cent. of bilious matter), and 2 24 cent. of fluid water removed with the urine and feces. (Op. cit.) Such is the elucidation, so far as it has been carried by experiment, of the results of starvation, and of the nature of the products which, by the influence of the atmosphere, are thrown off from the animal system. The next object of interest which has attracted attention, has been the increase of an animal in weight and bulk. An experiment on a cat, weighing 2177 grammes, has shown that the animal in eight days consumed 1886 grammes of flesh, 27 4 grammes of fat, and increased in weight by 337 grammes. During the experiment, 62 36 grammes of nitrogen were eliminated by the urine. It was calculated that the increase in weight depended partially on the deposition in the system of 40 16 grammes of muscular matter from the food of 145 42 grammes of fat, 178 grammes salts with sulphur, and 343 15 grammes water. Such researches being made with pure animal matter as food, it is easy to perceive that the increase of the animal depends on the simple assimilation or deposition of the animal matter already formed; but when an animal becomes fat by the consumption of vegetables, the question of the origin of the muscle and fat from such a source becomes
a legitimate subject of discussion. The nitrogenous matter of vegetables has now been identified with similar bodies found in animals, and therefore we can readily account for the supply of the waste of muscle, by the assimilation of nitrogenous vegetable food. The origin of the fat in animals fed on the produce of plants is not so obvious.

John Hunter had long ago, in his admirable observations on bees, found (Phil. Trans. vol. lxxxii. 128, 1792) that these creatures collect farina or pollen, deposit it at the bottom of their cells, and that other bees knead it and "work it down into the bottom," or spread it over what was deposited there, before converting it into the consistence of paste (bee-bread); this he discovered in the interior of the maggots: he therefore infers that it is the food of this early condition of the bee, and is not intended "to make wax." The bees when caught returning home, were found with the fine transparent terminal gullet-bag full of honey. When examined on going out in the morning this bag was empty, from which Hunter concluded that the honey was either regurgitated for preservation as future aliment, or passed into the stomach. He shows that the bee bread is not wax, and concludes that the wax is formed by the bees themselves; it may be called an external secretion of oil, and I have found that it is formed between the scales of the under side of the belly." On examining the bees through a glass hive while they were climbing up the glass, he could see that most of them had this substance, for it looked as if the lower or posterior edge of the scale was double, or that there were double scales, but he perceived it was loose, not attached. Finding that the substance brought in on their legs was farina, intended, as appeared from every circumstance, to be the food of the maggot, and not to make wax, and not having yet perceived any thing that could give the least idea of wax, he conceived these scales might be it, at least he thought it necessary to investigate them, and therefore took several on the point of a needle, and held them to a candle, when they melted and immediately formed themselves into a round globe; on which he no longer doubted that this was the wax, which opinion was confirmed by not finding these scales but in the building season (ib.). It is a remarkable circumstance that foreign chemical physiologists who have interested themselves in this question, and who have merely confirmed Hunter's observations, omit to mention even his name, while they notice that of Huber, a subsequent inquirer.

But that the oil of the food is incapable of supplying the fat of the animal, or of the butter of milk, is clearly established. One of the earliest experiments on this subject may be cited—two cows were found to have, in the total food consumed, 10.924 lbs. of oil and wax, while the butter of the milk amounted to 72.26 lbs., and the oil and wax in the dung was 52.5 lbs.; showing an excess of 23.82 lbs. of oil in the butter and dung over what originally existed in the food. The conclusion is inevitable that starch and sugar, assisted by the nitrogenous matter, must have yielded fatty material.—R. D. Thompson, Trans. Med. Chirurg. Soc., 1816, vol. xxix.

According to the present views of those best acquainted with this subject, the non-nitrogenous food is that which is especially destined for the production of animal heat, the oxygen of the air yielding heat when it unites with its carbon and hydrogen. "The heat which is produced by respiration is similar to that which is produced by the inflammation of combustible bodies, with this difference, that in the latter instance the fire is separated from the air, in the former from the blood." (Adair Crawford's Exper. on Animal Heat, 1779, p. 76.) It is to Crawford that the theory of animal heat is usually attributed. The French claim the honor for Lavoisier. There is no doubt that the latter was engaged with the subject about the same period, but the date of his publication is doubtful, as at that period French writings were usually ante-dated. The doctrine of animal heat, as originally suggested by Crawford, still stands its ground. All the arguments opposed to it are merely trifling attacks upon little indentations in the great curve, which expresses the average theory. When we compare the staple articles of food with the blood, we shall find in the latter fluid corresponding bodies to those constituting the nutrient, as appears in the following parallel columns:

<table>
<thead>
<tr>
<th>Nitrogenous matter</th>
<th>Non-nitrogenous matter</th>
<th>Salts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casein</td>
<td>Butter</td>
<td>Sodium chloride of potassium,</td>
</tr>
<tr>
<td>Albumen</td>
<td>Sugar</td>
<td>of sodium,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbonate of soda,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phosphate of soda,</td>
</tr>
</tbody>
</table>

**Milk**  | **Flour**  | **Blood**  |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogenous matter</td>
<td>Casein.</td>
<td>Fibrin.</td>
</tr>
<tr>
<td>Non-nitrogenous matter</td>
<td>Butter.</td>
<td>Oil.</td>
</tr>
<tr>
<td>Non-nitrogenous matter</td>
<td>Sugar.</td>
<td>Starch.</td>
</tr>
<tr>
<td>Non-nitrogenous matter</td>
<td>Chloride of potassium.</td>
<td>Fats and oils.</td>
</tr>
<tr>
<td>Non-nitrogenous matter</td>
<td>of sodium.</td>
<td>Sugar.</td>
</tr>
</tbody>
</table>

**Milk**  | **Flour**  | **Blood**  |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogenous matter</td>
<td>Casein.</td>
<td>Fibrin.</td>
</tr>
<tr>
<td>Non-nitrogenous matter</td>
<td>Butter.</td>
<td>Oil.</td>
</tr>
<tr>
<td>Non-nitrogenous matter</td>
<td>Sugar.</td>
<td>Starch.</td>
</tr>
<tr>
<td>Non-nitrogenous matter</td>
<td>Chloride of potassium.</td>
<td>Fats and oils.</td>
</tr>
<tr>
<td>Non-nitrogenous matter</td>
<td>of sodium.</td>
<td>Sugar.</td>
</tr>
</tbody>
</table>
Law of the Balance of the Food.—The older opinions respecting the nature of nutrition seem to have been that the stomach and digestive organs possessed the power of assimilation, as it was termed. Although this expression might still be used in a restricted sense, the former meaning which was attached to it was of a much more extensive nature, and implied a power in the animal system which we now know is not possessed by it. Indeed, a comparatively slight acquaintance with medical writers, up to even a recent date, is sufficient to teach us that a belief existed that almost any species of organic matter, when subjected to the assimilating powers of digestion, could be rendered serviceable in the support of the body. The great discovery of Beccaria in 1742, in his analysis of flour, ought to have produced a greater revolution in dietetics than it appears to have done. He first observed, that if wheaten flour be washed with water on a sieve, the water becomes milky by the mechanical diffusion of the starch, which in time subsides, while a material like glue, which is not miscible with water, remains. He termed the portion carried away by the water starch, and the soft tenacious residue he denominated gluten (now known to consist of fibria, gluten, casein). He identified the starch with vegetable matter, while the glutinous portion appeared to be endowed with the character usually attributed to animal matter, and this led him to propose two very simple tests by which the vegetable and animal substances, that is, matters containing nitrogen, may be readily discriminated. When vegetable, or non-nitrogenous bodies are digested in water, they do not putrify, but ferment and yield as a product a vinous or an acid fluid. With these starch corresponds. Animal substances, on the other hand, under the same conditions, putrify and corrupt, and afford a putrid or ammoniacal fluid. Again, distillation supplies a valuable distinguishing test of the products of the two kingdoms. Vegetable or non-nitrogenous matter, when subjected to this operation, yields an acid product, and a heavy black oil, similar to pitch. Such are the characters of starch. Gluten, like animal or nitrogenous bodies, affords an alkaline spirit—a volatile alkaline salt (carbonate of ammonia), first a yellow, then a black oil, and finally there is left, by intense heat, a black spongy matter (charcoal), which, in an open fire becomes a white insoluble earth (bone earth). These remarkable observations struck Beccaria with surprise, as he found no traces of any such results in previous writers. For when he had discovered gluten by the simple process already detailed, it appeared to him so identical with animal matter that, if he had not himself extracted it from wheat, he should have mistaken it for a product of the animal world. (Hist. de l'Acad. de Bologne, Collect. Acad. x. 1.) These views, which are in exact consonance with the most recent ideas entertained by chemical physiologists, appear to have produced little fruit, although the question put by the author, "Are we composed of other substances than those which serve for our nutrition?" distinctly exhibits the view which he took of the subject. During the present century, a large amount of experiment has clearly demonstrated that animals cannot subsist on starch, sugar, or other foods destitute of nitrogen; and therefore M. Debeaune fairly deduced that the animal system possessed no power of assimilating nitrogen from the air. (Magendie.) Further consideration led to the conclusion that milk constitutes the type of what nutriment should be, since it is supplied for animal support by nature at the earliest period of human existence (Proust), and contains nitrogenous matter, oil, and sugar. Afterwards, experiments were made to determine the amount of nitrogen in food, and the relative value of nutriment was tabularly stated, in dependence on the ratio of nitrogen present in each species (Bunsenwald, Ann. de Chim. lxiii. 225, 1856), a method which has been superseded. It was subsequently inferred that nitrogenous nutriment supplied the waste of the muscular tissue, while the non-nitrogenous constituents of the food served for respiratory purposes, or the production of animal heat by obviating the too rapid transformation of the muscular elements of the body. (Lichten, Organische Chemie, 1842.) This was the true key to the solution of the problem as to the function of the nitrogenous and non-nitrogenous food, and it laid open a wide field for inquiry in reference to the application of rational systems of dieting to the animal system. For example, it was found in a series of experiments conducted for the British Government in 1845, that in a stall-fed cow in one day, taken from an average of several months, the amount of food conveyed into the circulation of the blood of the animal, was 11.56 lbs. weight, and when the nature of this mass of nutriment was subjected to chemical inquiry, it appeared that 1.56 lbs. consisted of nitrogenous matter, and 13 lbs. of non-nitrogenous food. When the relation between these two quantities is calculated, it results that the nitrogenous is to the non-nitrogenous food as 1 to 8.53, as in the case of an animal at rest. This observation led to researches into the relative constitution of food as employed by different nations; and the deduction was made that it is a law of nature that animals, under the different conditions of rest and exertion, require food in which the relation of the nutrient or nitrogenous food is different in reference to the non-nitrogenous or heat-producing (calorific) constituent;—that the animal system may be viewed, as, in an analogous condition to a field, from which different crops extract different amounts of matter, which must be ascertained by experiment,—an animal at rest consuming more calorific food, in relation to the nutritive constituents, than an animal in full exercise. From the analyses then instituted the following table was constructed.
NUTRITION.

Approximate relation of nutritive or nitrogenous to calorifant matter. —

| Milk food for a growing animal | 1 to 2 |
| Beans | 1 " 2½ |
| Peas | 1 " 3 |
| Linseed | 1 " 5 |
| Scottish oatmeal | 1 " 7 |
| Wheat flour | 1 " 8 |
| Semolina | Food for an animal at rest |
| Indian corn | 1 " 9 |
| Barley | 1 " 10 |
| Potatoes | 1 " 11 |
| East India rice | 1 " 20 |
| Dry Swedish turnips | 1 " 28 |
| Arrowroot | 1 " 40 |
| Tapioca | 1 " 40 |
| Sago | 1 " 40 |
| Starch | 1 " 40 |

These proportions will consequently vary considerably according to the richness of the grain or crop, and hence similar tables which have been subsequently published by others will be found to differ in some of the details from the preceding data; but the facts now stated — given as approximate — are probably as good averages as could be selected. — R. D. Thompson, Medico-Chirurgical Trans. xxix. and Experim. Researches on the Food of Animals, 1846, p. 162.

A consideration of the nature of the relations exhibited in this table is sufficient to afford an explanation of many practical results in the subject of diet. Thus in the young of the mammalia — including the human race — the heat-forming or non-nitrogenous food is only two or three times greater than that of the nitrogenous food which is the supporter of the muscular tissue of the body, because the child requires a larger amount of matter to repair its daily waste, and likewise an additional portion to enable it to increase in bulk. Nature has so arranged that, in the milk of the mother, every three or four ounces of the solid particles of that fluid shall supply one ounce of nitrogenous material. When we compare this result, which is a fact independent of all theoretical considerations, with the condition of the class of starches at the close of the table — known under the names of arrow-root, tapioca, and sago — we see, that to supply these to children would be to deprive them of the possibility of obtaining the requisite nourishment demanded by the wants of their systems; since to communicate one ounce of nitrogenous matter to them, it would be necessary that they should swallow 26 ounces of starch, a proceeding which, upon mechanical considerations alone, would be impracticable. Beans and peas have been found much more effective in supporting the strength of animals subjected to hard labor than grass or other soft fodder; and the reason for this on the principles under review is obvious. A cow weighing about 1,000 pounds was found to introduce into its system 15'28 pounds of the solid portions of grass daily; but this was extracted from 100 pounds' weight, of fresh grass, and contained 1'56 pound only of nitrogenous matter, and 13'1 of heat-forming or respiratory food. To convey this large mass of nutriment into the stomach required the action of the primary organs of digestion during the whole day; while to have introduced a similar amount of nitrogenous matter in the shape of beans, not above 20 pounds would probably have been necessary. Thus by substituting the concentrated form of beans for the bulky grass, a great saving of time is effected in conveying the digestive materials into the current of the blood. The bulky nature too of grass — from 100 lbs. of which only 13'4 pounds of nutritive matter can be extracted — affords an explanation of the more complicated nature of the stomachs of ruminant animals than of the human family, which practical experience, or instinct, as some would term it, has taught to select more concentrated forms of food.

The primary and original food of man, whatever speculators may say to the contrary, is milk, a fluid of purely animal origin. If those who are to regulate diet are not guided by scientific knowledge, and do not exercise their judgment, they might be inclined to draw from this fact the inference, that the proper nutriment of man is animal food. This deduction might be defended with some show of reason to the exclusion of a vegetable diet. But observation having proved that animals can subsist upon a vegetable as well as upon an animal regimen, and scientific research having satisfactorily demonstrated that the constituents of the two kinds of nutriment, when well selected, are identical, the one-sided position must yield to the light of knowledge.

It will be now from these details, in some measure, understood how it happens that for all conditions of society, vegetable food may not be advisable; and that vegetarianism, while it may be applicable in some instances, would be prejudicial in other individual cases. The
poetical and merciful sympathies of Pythagoras it is impossible altogether to set aside, although it is unnecessary to echo the sentiment that "the man of cultivated moral feeling shrinks from the taking the life of the higher grade of animals, and abhors the thought of inflicting pain and shedding blood;" for even the Greek philosopher, although he objected to slay cattle for the purposes of human food, sacrificed, in a fit of enthusiasm, without any compunction, one hundred oxen in an excommunication of his discovery that a square on the
hypothenuse of a right-angled triangle is equal to the sum of two squares on the base and the perpendicular. Indeed, such a cruel result of a scientific discovery has appeared to his admirers so inconsistent, as to induce them to suggest that the oxen were made of wax. It is more probable that, as in modern times, other causes had tended towards a vegetarian conclusion. But his arguments may be heard: "Forbear, mortals, to pollute your bodies with abominable food. Wild beasts satisfy their hunger with flesh, although not all; for the horse, flocks, herds, feed on grass. But those which have a wild and cruel temper, Armenian tigers, angry lions, bears, and wolves rejoice in bloody food. What a wicked crime it is that bowels should be buried in bowels, and that one greedy body should fatten on another crammed into it, and one animal should live by the death of another!"—Ovid, Metamorph. xv. 2.

A practical application of the law involved in the table to the nourishment of horses will now be understood. If we represent the amount of muscle removed from the body of a horse to be 2 lbs. per day, while the amount of food consumed in the production of heat is 12 lbs., it is obvious that, to make up for this loss, we should never think of giving to the animal food containing 2 lbs. of albuminous or muscular matter and 52 lbs. of non-nitrogenous or heat-forming matter, such as sago; neither should we give a diet containing 2 lbs. of albuminous materials and 22 of caloriferous ingredients, such as turnips; but we should endeavor to administer nourishment which contained as nearly as possible the ingredients which the animal's consumption required. This object would be nearly attained by the use of oats, which would give for every 2 lbs. of muscular matter, 10 lbs. of heat-forming constituents; or by barley 2 to 14. A mixture, then of the two grains would supply the nourishment required by the animal, or the same result would follow by the employment of beans and hay. The principle of the arrangement of the food being understood, the nature of the nutriment can be easily calculated for the different conditions in which the animal may be placed.

A continuous study of the table brings us to oatmeal, which constitutes, even at the present day, an essential element in the support of the Scottish peasant. Wheat is no doubt cultivated to a greater extent than formerly, in northern latitudes, but from the analyses which have been published, it appears to be an unquestioned fact that the amount of nitrogen increases, within certain limits, in this species of the cereals as the plant advances from the equator. But one cause of the high nitrogenous position held by oatmeal is, that as it is usually prepared, it retains much of the bran, which is rich in nitrogen; while in the predominant form of wheat-flour this ingredient is in a great measure removed. When, however, the bran is retained in the flour, as when the entire wheat-seed is ground up and not sifted, the superiority of the nutritious value of oatmeal over wheat-flour has not been demonstrated. The substance termed semolina in the table, consists of bruised wheat from the south of Europe, and corresponds with the manna group of the north of Europe, and the sojooj of India. Illustrations of the fatal effects of this practice have been afforded by feeding calves on sago, a form of farinaceous matter, as exhibited by the table, which is artificially disturbed in its natural equilibrium. For it will be remembered that arrow-root, tapioca, and sago, as they occur in commerce, are the storehouses of natural flours which have been washed by repeated applications of water, until they have been to a great extent deprived of their nitrogenous matter, and of their saline ingredients. Calves fed on this form of food, have been observed to become most ready victims to passing epidemics. (Smith of Drumtoon.) For a brief period they seem not to suffer, but on the approach of disease they were readily subjected to its action, and rarely recovered. The same reasoning will apply to the human species. For if a child were fed on milk entirely (its composition being 1 nutritive to 2 heat-forming, the proper blood salts), and threw as nature intended it should do on this species of aliment, could we expect that the infant would be equally nourished, when a portion of this type of food was replaced by arrow-root, containing 1 nutritive to 26 of caloriferous material, without any saline ingredients required to produce blood? To expect such a result would be opposed to experience and to all analogy. From the table we may infer that the food destined for an animal in full exercise, should range between milk and wheat-flour, according to the nature and extent of the demands upon the system. Milk may therefore be employed with a certain amount of the cereals with probable advantage. When the food is preserved by nature, by means of combining water, as in succulent vegetables, from the severe effects of the vicissitudes of the atmosphere, the most efficient nutriment is afforded to the inferior animals. This is shown in the following table, where an average is given of the products of two cows, in milk and butter, by different species of aliment. The largest amount is obtained from grass, which preserves its equilibrium most firmly during
NUTRITION.

the changes of the seasons, while hay and cereal crops, from their want of succulence, and therefore of protection from the rain and fermenting influences, are less influential in effecting a steady product.

<table>
<thead>
<tr>
<th></th>
<th>Milk in 5 days</th>
<th>5 days.</th>
<th>3 lbs.</th>
<th>3 lbs.</th>
<th>3 lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>114</td>
<td>3.10</td>
<td>3.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley and hay</td>
<td>107</td>
<td>3.43</td>
<td>3.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malt and hay</td>
<td>102</td>
<td>3.20</td>
<td>3.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley, molasses and hay</td>
<td>107</td>
<td>3.44</td>
<td>3.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley, linned, and hay</td>
<td>108</td>
<td>3.48</td>
<td>4.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans and hay</td>
<td>105</td>
<td>3.72</td>
<td>5.27</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It had been found by experiment, that, not only in hay-making is the coloring matter of the grass removed or altered, but, particularly in moist districts, the sugar or heat-forming portion of this form of provender is washed out by the rains or destroyed by fermentation, while a certain proportion of the soluble salts absolutely required for the production of animal blood and milk is also removed by every shower which falls during the drying of the hay. In this table, the butter and milk of the cow may be supposed to represent the increase of body which a growing animal sustains during its infant years; while the richness of these forms of dairy-produce are the well-recognized tests of the value of the soil and pasturage upon which the animals have browsed. By a comparison of the relation of the different kinds of cereals we may improve one species by mixing it with another. By mixing one-third of Canada flour with two-thirds of Indian corn, a very good loaf is produced, and when equal parts of flour and oatmeal, or of barley, or of pea-meal are employed, a nourishing bread is formed. Beneficial results have also followed from the admixture of two or three different kinds of grain, and many of these forms of bread might be substituted with advantage for wheat flour in peculiar conditions of the system. The superior advantage of good wheat flour depends on the presence of gluten, an adhesive nitrogenous principle, which, during fermentation by the resistance which it presents to the escape of the carbonic acid, engenders that vesicular spongy condition which is considered the test of a good loaf. From the absence of this substance in other kinds of grain, they are of themselves incapable of affording a spongy loaf, and hence the presence of wheat flour is essential in all well-raised bread. A loaf may be made of equal parts of oatmeal and flour, which when fermented will be highly spongy. It is advisable in such a case to use foreign flour, which contains a larger proportion of adhesive gluten than is found in the wheat flour grown in our northern climate. It may be objected that the recommendation of such mixture is a direct invitation to bakers to adulterate their flour. But such mixtures are admitted by law with the provision that the letter M be affixed to the baker to the loaf. Indian-corn bread may be baked of good quality by a smaller admixture of flour than is necessary when oatmeal is the other ingredient. For this purpose it should be reduced to a fine meal, in smaller particles than is practiced in the United States. It may then be mixed with one-third its weight of best flour, and be fermented in the usual way. When thus baked, the best Indian-corn bread is always dark colored, and cannot be made much lighter than coarse wheat bread. The shade of color is yellowish. When Indian-corn bread appears white, the conclusion to be drawn is that the mixture consists of more than one-third of wheat flour. Even when one-half its weight of wheat flour is added to it, Indian-corn exhibits in the mixture its characteristic dark tint. See Bread. The position which potatoes hold in the nutritive scale, shows that although they are frequently used in the mode of preparing bread by fermentation, no advantage would be gained by augmenting their amount, since the aliment would thus be rendered more dilute and the statement of the poet confirmed:

"Bread has been made (indifferent) from potatoes."—Byron.

At the present day the New Zealanders are affected, to the extent, in some districts, of 20 per cent., in others of 10 per cent., with external marks of scrofula, a fact which was not observed by Capt. Cook. This disease is therefore inferred to be a modern innovation, brought about by the natives having lived since Cook's time on potatoes, which have superseded fish and pig's flesh in a great measure. It is only necessary to see a child after a month's residence in the house of a European, to have an indication of the magic influence a better diet would have on the whole race. The puny limbs of the young savage grow stouter, the protruberant belly disappears, and traces of red blood can be seen through the nut-colored skin of his infant face.—A. S. Thomson's New Zealand, I. 216.

Further support of the law enumerated has been afforded by subsequent experiments (Freeman, Knapp, Plagfar, Libby). "A glance at these relations is sufficient to convince us that in choosing his food (when a choice is open to him), and in mixing the various articles of diet, man is guided by an unerring instinct which rests on a law of nature. This law prescribes to man as well as to animals a proportion between the plastic and non-nitrogenous constituents of his whole diet, which is fixed within certain limits within which it may vary accord-
ing to his mode of life and state of body. This proportion may, in opposition to the law of nature and instinct, be altered beyond these limits by necessity or compulsion, but this can never happen without endangering the health and injuring the body and mental powers of man. It is the elevated mission of science to bring this law of nature home to our minds; it is her duty to show why man and animals require such an admixture in the constituents of their food for the support of the vital functions, and what the influences are which determine in accordance with the natural law changes in this admixture." (Liebig, Fam. Letters on Chemistry, 1851, p. 362.) It has been shown that when a French soldier is fed on 1 lb. 10½ oz. of bread, he consumes in this ration 1 part of nitrogenous to 43 of non-nitrogenous material (Knapp), and that when pigs were fed on potatoes no augmentation could be detected in their weight. An increase was observed when the diet of the animal was potatoes, butter-milk, whey, and kitchen refuse, but the greatest improvement took place under what was termed a fattening fodder, consisting daily of 97 lbs. potatoes; ground corn 9 lbs.; rice-meal 64 lbs.; peas, 86 lbs.; butter-milk, whey, and kitchen refuse 92 lbs. (Bouasinghault). In these different modes of dieting, the following were the relations of the constituents of the food:

<table>
<thead>
<tr>
<th>Nitrogenous.</th>
<th>Non-nitrogenous.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td>1</td>
</tr>
<tr>
<td>Mixed food</td>
<td>1</td>
</tr>
<tr>
<td>Fattening fodder</td>
<td>1</td>
</tr>
</tbody>
</table>

The German farmer renders the proportion more nearly allied between the proximate principles of the potato, by fermenting and distilling from them a spirit, and giving the residue thus supplied with a less proportion of heat-forming material to his cattle. It has been supposed in other countries that the German agriculturist is a distiller. On the contrary the production of spirit is a result of what he has found to be, by experience, a valuable method of improving the alimentary character of the potato (Knapp). All of these explanations have been deduced since the law of the equilibrium of the food detailed above was detected.

The tables on the next page are illustrations of the same law.

In these tables the ounces of the original are calculated as grammes, and the last column gives the relation of the nitrogenous or flesh-forming part of the food, to the non-nitrogenous or heat-forming part of the constituent ingredients of the aliment, instead of, as in the original, the proportion between the carbon of these constituents of the food being estimated. The table is read thus: an English soldier consumes weekly 11,703 grammes (a gramme equal to 15.44 grains) of food. In this food 1,119 grammes are nitrogenous or flesh-forming matter; 3,837 non-nitrogenous or heat-producing material; 523 mineral substance; the organic matter containing 2,219 grammes carbon. The relation of the nitrogenous to the non-nitrogenous matter is as 1 to 3.59. From this table the results have been deduced that soldiers and sailors consuming 35 ounces of nitrogenous or flesh-forming food weekly, and 70 to 74 ounces of carbon, the proportion of the carbon in the flesh-forming to that in the respiratory or heat-forming food is as one to three. Older persons require only 25 to 30 flesh-forming matter weekly, and from 72 to 78 respiratory food; the relation of the carbon in these is as 1 to 5. Boys of from ten to twelve years of age require 17 ounces of flesh-forming matter, the relation of the carbon in the flesh-forming to the heat-producing aliment being as 1 to 5.4. In workhouses and jails, less heat-producing matter is consumed, in consequence of the shelter and heat supplied artificially to the inmates. In prisons, where hard labor is in force, the consumption of flesh-forming or nitrogenous nutriment increases. It has been estimated that in a man weighing 140 lbs., the weight of the flesh-forming matter of the blood is 4 lbs., that of the muscular tissue 273 lbs., and in the bones 9 lbs., making a total of 361 lbs., and that in the course of 18 weeks these 361 lbs. are introduced into the system. (Plough, New Edin. Phil. Journal, 1854, 56, 262.) The author of this elaborate and valuable table has justly remarked that the old mode of estimating the value of dietaries, by merely giving the total number of ounces of solid food used daily or weekly, and quite irrespective of its composition, is most erroneous; and he quotes an instance of an agricultural laborer, in Gloucestershire, who in the year of the potato famine subsisted chiefly on flour, consuming 163 ounces weekly, which contained 26 ounces of flesh-forming matter. When potatoes became cheaper, he returned to a potato diet, and now ate 321 ounces weekly, although they contained of true nutriment only about 8 or 10 ounces. A comparison of the six pauper dietaries formerly recommended, with the difference between the salt and fresh meats dietary of the sailor, &c., have no relation in equivalent nutritive value, but merely rely on absolute weight alone. It is by such dietaries, where the proper balance of the constituents is not preserved, that, although the appetite may be satisfied, the waste of the system is not adequately repaired. The health may appear not to be affected in the absence of epidemics, but, under such a dietary as that alluded to, a maximum of labor cannot be obtained from a workman; a frail constitution is engendered, which acts as a fertile soil to misfortune of various kinds. These seeds of disease taking root, are rapidly developed into maladies, like the rank fungi of damp and dismal cellars.
### NUTRITION.

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</thead>
<tbody>
<tr>
<td>English soldier</td>
<td>11708 Grms.</td>
<td>1119 Grms.</td>
<td>3937 Grms.</td>
<td>152</td>
<td>2219</td>
<td>3-50</td>
<td></td>
</tr>
<tr>
<td>&quot; sailor (fresh meat)</td>
<td>9250 Grms.</td>
<td>1078 Grms.</td>
<td>3155 Grms.</td>
<td>74</td>
<td>2953</td>
<td>3-92</td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; (salt meat)</td>
<td>8978 Grms.</td>
<td>1274 Grms.</td>
<td>4092 Grms.</td>
<td>187</td>
<td>2706</td>
<td>3-69</td>
<td></td>
</tr>
<tr>
<td>Dutch soldier, in war</td>
<td>6130 Grms.</td>
<td>1090 Grms.</td>
<td>3160 Grms.</td>
<td>57</td>
<td>2293</td>
<td>3-90</td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; in peace</td>
<td>11837 Grms.</td>
<td>759 Grms.</td>
<td>2306 Grms.</td>
<td>128</td>
<td>2191</td>
<td>4-55</td>
<td></td>
</tr>
<tr>
<td>French soldier</td>
<td>10742 Grms.</td>
<td>1029 Grms.</td>
<td>3955 Grms.</td>
<td>98</td>
<td>2184</td>
<td>3-84</td>
<td></td>
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<tr>
<td>Bavarian soldier</td>
<td>7492 Grms.</td>
<td>652 Grms.</td>
<td>3161 Grms.</td>
<td>108</td>
<td>1933</td>
<td>4-55</td>
<td></td>
</tr>
<tr>
<td>Hessian soldier</td>
<td>13090 Grms.</td>
<td>712 Grms.</td>
<td>4210 Grms.</td>
<td>-</td>
<td>2384</td>
<td>5-91</td>
<td></td>
</tr>
</tbody>
</table>

### Dietaries of Children.

- Christ's Hospital, Hertford: 6687 Grms., 531 Grms., 1897 Grms., 76 Grms., 1213 Grms., 3-57 kg.
- Chelsea Hospital boys' school: 7552 Grms., 491 Grms., 2888 Grms., 185 Grms., 1785 Grms., 4-45 kg.
- Greenwich Hospital: 7131 Grms., 570 Grms., 2685 Grms., 81 Grms., 1637 Grms., 4-71 kg.

### Dietaries of Aged Persons.

- Chelsea: 10928 Grms., 905 Grms., 3187 Grms., 114 Grms., 2180 Grms., 4-85 kg.
- Gillespie's Hospital, Edinburgh: 4829 Grms., 651 Grms., 2858 Grms., 73 Grms., 2210 Grms., 4-54 kg.
- Trinity Hospital: 5944 Grms., 608 Grms., 3014 Grms., 104 Grms., 1637 Grms., 4-71 kg.

### Dietaries of Aged Poor.

- 1st class: 626 Grms., 2743 Grms., 101 Grms., 1681 Grms., 4-33 kg.
- 6th " 21 " London: 434 Grms., 2725 Grms., 88 Grms., 1535 Grms., 5-00 kg.
- Mean of all English counties: 631 Grms., 3665 Grms., 121 Grms., 1796 Grms., 4-50 kg.
- City poorhouse: 3313 Grms., 412 Grms., 1547 Grms., 51 Grms., 975 Grms., 3-75 kg.

### Dietaries of English Prisons.

- 2d class, above 7 not above 21 days hard labor: 6393 Grms., 472 Grms., 3463 Grms., 107 Grms., 1834 Grms., 7-34 kg.
- 4th, 7th, 8th classes, above 6 weeks not above 4 months' hard labor: 8405 Grms., 649 Grms., 3900 Grms., 156 Grms., 3162 Grms., 6-90 kg.
- 5th class, above 4 months' hard labor: 10092 Grms., 628 Grms., 4042 Grms., 131 Grms., 2270 Grms., 6-43 kg.

### Bengal Prisons.

- Without labor: 6035 Grms., 571 Grms., 5051 Grms., 64 Grms., 2364 Grms., 8-85 kg.
- With labor: 9464 Grms., 872 Grms., 5017 Grms., 92 Grms., 2819 Grms., 6-78 kg.

### Bombay Prisons.

- All classes, without hard labor: 5034 Grms., 867 Grms., 3142 Grms., 63 Grms., 2130 Grms., 7-98 kg.

### Arctic and other Dietaries.

- Farm laborers, Gloucestershire: 5063 Grms., 825 Grms., 3299 Grms., 34 Grms., 2323 Grms., 3-97 kg.
When the constitution of the food is compared in its relations of muscular to fatty matter, with the proportion of these ingredients deposited in animals, the result is of interest. Carefully conducted experiments on the large scale upon animals have shown, that in fat animals killed and carefully analyzed after death, the carcase of the fat ox contained 1 part of nitrogenous matter to 2 1/2 fat; in that of the fat sheep the relation was 1 to 4; in that of the very fat sheep, 1 to 6; and in the moderately fat pig, 1 to 5. In the lean sheep the proportion was 1 to 12; in the lean pig, 1 to 2. The average composition of such well fattened and lean animals was found to be nearly

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Fat animal</th>
<th>Lean animal</th>
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<tbody>
<tr>
<td>Nitrogenous matter</td>
<td>12 1/2</td>
<td>12 87</td>
</tr>
<tr>
<td>Fat</td>
<td>38</td>
<td>25 1/2</td>
</tr>
<tr>
<td>Mineral matter</td>
<td>3</td>
<td>4 5</td>
</tr>
<tr>
<td>Water</td>
<td>31 5</td>
<td>57 33</td>
</tr>
</tbody>
</table>

It was found by an analysis of some of the most important animals fed and slaughtered as human food, that the entire bodies, even when in a reputed lean condition, may contain more dry fat than dry nitrogenous substances. Of the animals ripe for the butcher, a bullock and a lamb contained rather more than twice as much dry fat as dry nitrogenous matter; while in a very fat pig and sheep, the proportion was 1 muscular matter to 4 fat, and in a moderately fat sheep the fat was three times greater than the nitrogenous matter.—Laws and Gilbert, Proc. Royal Society, No. 62, 548. —June, 1858.

Use of Fermented Liquids in Nutrition.—In the very earliest periods of human history wine appears to have been known, and to have been of the same nature with that which we now use, as the Hebrew term employed to designate the stimulating liquor indicates it as being derived from a fermenting origin, (Parous, Antig. Heb. 396.) This, together with its wide-spread use, has frequently been considered as an argument in favor of its necessity. But its ubiquity cannot be substantiated. The native Indians of North America, amounting to some millions in number, were unacquainted with fermented products until they were visited by the white man, (Culm.) When the Spaniards first visited South America, they were astonished at the constitutional temperance of the natives, which, in their opinion, far exceeded the habits of the most mortified hermits, (Robertson, iv.) In Patagonia, within the last 200 years, the inhabitants, when offered a bottle of brandy, would not drink, (Sir J. Norburne, in 1609, Soc. 1711, p. 50.) If we refer to Africa, we have the authority of the great traveller who has penetrated into the interior of that mysterious continent, that, true to their faith, the Mohammedans "drink nothing but water," (Park,) and it is only among the Pagan negroes who have frequent intercourse with the coast in consequence of these being the reservoirs from which slavery emanates, and in such semi-civilized towns as Tripoli, that religion is placed in subjection to inebriating indulgences, and that "drunkenness is more common than even in most towns in England," (Lyon.) It is true that the ancient Gauls and Germanas, who, however, were somewhat civilized, made use of beer, but whether they did so habitually, or to excess, before they were contaminated by Roman customs, seems unlikely. Certain it is, that they had no wine of their own. The Gauls purchased their wine chiefly from Italy, and were exceedingly fond of it, (Diodorus,) and hence they are said to have been invited into that country by the delicacy of the Italian wines, (Livy, v. 52.) Even among the Romans, however, in the virtuous days of the Republic, strong drinks were not universally in favor, since it was fashionable, in order to make wine keep, to boil it down to one-half, (Vigil.) or one-third, (Pliny;) in other words, to distill away all the alcohol it contained. All the circumstances, indeed, with which we are acquainted, seem to support the view of the historian, that "it is in polished societies where intemperance undermines the constitution," (Robertson.) These facts seem to prove that alcohol is not a necessary of life. It remains to consider what its influence is upon the system. When fluids containing alcohol are introduced into the body of animals, the amount of carbonic acid evolved from the lungs speedily begins to diminish. The influence of even a small portion of wine begins to be appreciable in a very short space of time after it has been swallowed, so that we infer its power in this respect to be almost consonant with its arrival in the stomach. Alcohol itself possesses a similar effect, and the use of porter is attended by the same results. Numerous experiments have demonstrated that alcohol in every state, and in every quantity, uniformly lessens, in a greater or less degree, the quantity of carbonic acid elicited according to the quantity and circumstances under which it is taken. When taken on an empty stomach, its effects are remarkable; the depression is greatest almost immediately; after a short time, however, the powers of the constitution appear to rally, then it slacks again, and afterwards slowly rises to the standard. That the action of the alcohol in these cases depends on its influence on the nervous system, and not on its chemical action, is obvious from the fact that strong tea acts in a similar manner, and with the same degree of rapidity; three ounces of strong tea, in five minutes after being swallowed, depresses the amount of carbonic acid progressively, (Front, 1812.) Other ex-
experiments bear testimony to the wonderful effect of alcohol on the nervous system. Two ounces of alcohol, when injected into the stomach of a rabbit, rendered it immediately insensible, just as if the animal had been violently struck on the head. Two draughts placed in the stomach of a cat, instantly made it struggle violently and fall on its side perfectly motionless and insensible. It is remarkable, too, that the effects of alcohol, and of injuries, more particularly concussion of the brain, so closely resemble each other, that the most accurate observer cannot often distinguish them, except from the history of the case. (Sir B. C. Brodie.) When alcohol is introduced in excess into the system, the arterial blood appears to retain the venous condition, and thus asphyxia may be produced, (Bouchardat.) Alcohol, it is affirmed, has been detected in small proportion in the air exhaled from the lungs, and also in the blood of drunkards, while a considerable portion of acetic acid, one of the products of its combustion, has been observed in the blood after the use of this fluid, (ib.) These views, therefore, tend to the conclusion that alcohol, in its all forms, produces an alteration in the usual phenomena consequent upon digestion; that this influence is analogous to that of those causes which produce depression of the nervous centres, and therefore its employment by preference as a heat-supplying agent to the animal system in cases of health, is a procedure involved in very great doubt. The argument in favor of the colorific nature of alcohol is, that as it disappears in the system it acts as an element of respiration, and although its constituents do not possess by themselves the property of combining with oxygen at the temperature of the body, and forming carbonic acid and water, yet it acquires, by contact with bodies susceptible of this combination, this property in a higher degree than fat, &c., (Liebig.) If, then, alcohol be thus capable of conversion into carbonic acid by the use of the same principle, how are we to explain the fact that alcohol diminishes the amount of carbonic acid in the expired air? The answer has been, that as alcohol contains a large amount of hydrogen, which, by union with the oxygen of the air, passes off from the lungs in the form of vapor of water, the diminution of carbonic acid is a necessary result of the use of this stimulant. But there is a remarkable fact which appears to throw doubt on this view, viz., that in addition to the analogous and instantaneous action of tea, as long as the effects of alcohol are perceptible to the feelings of the individual who has swallowed it, the quantity of carbonic acid is below the standard. The effects of drinking go off with frequent yawnings, and with a sensation as if awakening from a sleep. Under these circumstances the quantity is generally much above the standard, and hence it would seem that the system is freeing itself from the retained carbon, (Prout.) The phenomena of yawning, sighing, &c., appear to have evidently the effect of throwing off a quantity of carbonic acid retained in excess in the system, since sleep and depressing passions seem to operate by diminishing the amount of carbonic acid. There may be various reasons, too, for inferring that alcohol is not thrown off in the form of colorless, odorless, gases by the lungs. The offensive ethereal smell retained in the breath of the drunkard for many hours after the introduction into the stomach of the cause of his inebriation, seems to favor the view that other products besides carbonic acid and the vapor of water result from the use of alcohol. That alcohol does not occupy a very high position as a colorific agent, is evident from its comparative operation in heating the body when cooled and depressed by external cold.

Hot fluids are familiarly known to all to be much more efficient in raising the heat of the body than raw spirits or strong fermented fluids, which have a less action unless combined with hot fluids. The influence of the use of spirits has been tested in the army, and it has been found in India, that when a regiment consumed from 10,000 to 14,000 gallons, the mean annual mortality was 76, and when the amount was reduced to 2,000 to 3,000, the mortality fell to 24, out of the same strength. An interesting experiment has been in operation during the last 20 years in the United Kingdom Provident Institution. During that period this society has insured a distinct section of abstainers who number above 5,000, and it has likewise a more numerous section of the general public. During the first 6 years, out of 2,960 members, only 18 died, equivalent to a loss of 9 per cent., while the office of the Society of Friends, who are distinguished for their care of health, lost in the corresponding period of their history 28 per cent. The most recent report from this institution, after 15 years' existence, gives a return of 19 per cent. of profits in favor of the abstainers, over the section of non-abstainers; although that division likewise contains many individuals of the latter class.

Influence of Tea and Coffee on Nutrition.—The experiments already referred to indicate that tea delays the regular changes of the body of animals, since the carbonic acid exhaled from the lungs declines in quantity under the influence of tea, (Prout, 1815.) Coffee, from its containing the same principle, might be inferred to be possessed of a similar action, and this has been found to be the case; but it has been found, in addition, that a decoction of coffee communicates greater activity to the circulation and nervous system. The delay which it effects in the metamorphosis of the tissues appears to be occasioned by the empyreumatic oil of the berry, which likewise produces increased action of the sweat pores, of the kidneys, and an accelerated motion of the intestinal canal; while the effects of caffeine
in excess are increased activity of the heart, headache, delirium, &c. (Lehmann, 1853.) Coffee and tea, as usually employed, appear therefore to act as stimulants and as agents by which the conversion of the solids of the body into soluble and gaseous products is considerably delayed. Their influence is analogous to that of alcoholic fluids when these are taken in moderate quantities, although there is no evidence that they are capable of producing organic disease, such as inevitably attends the consumption of increased doses of alcoholic fluids. The Turcomans employ tea in their wanderings as an article of nutriment, and have discovered, by long experience, what has been confirmed by chemical research, that the leaves of tea contain a large amount of nitrogenous matter, which is not, however, dissolved in the usual process of infusion. One ounce of tea-leaves and an equal weight of carbonate of soda are boiled by the Turcomans in a quart of water for an hour. The liquor is then strained and mixed with ten quarts of boiling water, in which an ounce and a half of common salt have been previously dissolved. The whole is then put into a narrow cylindrical churn along with butter, and well stirred with a churning-stick till it becomes a smooth, oily, and brown fluid, of the color and consistence of chocolate, in which form it is transferred into a teapot. (Mooret.) The soda has the effect of taking up the casein or curd, a most nutritive nitrogenous compound, and which is present in large quantity.

Influence of Tobacco and Opium on Nutrition. — It has been observed in favor of the practice of smoking tobacco, that even the most primitive tribes indulge in this practice. It was a correct observation, the practice may be pronounced to be a savage one, and to be connected with the conditions of savage life. The North American Indians all smoke, but when uncontaminated by intermixture with the whites, tobacco is unknown to them. The material which they employ is the prepared bark of a species of willow. The presence of such products of combustion in the system appear like tea and coffee, which have also been discovered in primitive nations to delay the degradation of the tissues and husband the food. The American Indians, who live entirely upon animal food, and who have impressed on them a restless and wandering existence, from the nature of their food—first from the difficulty experienced in obtaining animal heat—from the metamorphosis of the nitrogenous tissues—use the smoke of vegetable matter to make their food last longer. Tobacco and opium when smoked appear to have a similar action, but they likewise influence the nervous system and occasion a stimulating influence, which is apparent in the vivacity of the eye, particularly with opium as it is smoked in China. The practice of opium-eating, as in use among the Turks and the islands of the Indian Ocean, is totally distinct in its physiological results; a wild inebriety being often produced, which, if persisted in, conducts to a lamentable end. In a case which occurred to us, the liver was entirely destroyed by fatty degeneration.—R. D. T.

OIL OF VITRIOL is the old name of concentrated SULPHURIC ACID.

OILS. Chevreul considers all the oils to be composed of two, and sometimes three different species, viz., stearine, margarine, and oleine; the consistence of the oil or fat varying as either of these predominates. These bodies are all compounds of glycerine, with a fatty acid. At all ordinary temperatures oleine is liquid; margarine is solid, and melts at 110° F. Sterarine is still more solid, and melts at about 150° F. The two latter may be prepared from pure mutton fat, by melting it in a glass flask, and then shaking it with several times its weight of ether; when allowed to cool, the stearine crystallizes out, leaving the margarine and oleine in solution. The soft mass of stearine may be strongly pressed in a cloth, and further purified by recrystallization from ether. It forms a white friable mass, insoluble in water, and nearly so in cold alcohol; but boiling spirit takes up a small quantity. It is freely soluble in boiling ether; but, as it cools, nearly all crystallizes out. Margarine may be prepared from the etheral mother-liquor, from which the stearine has separated, by evaporating it to dryness; the soft mixture of margarine and oleine is then pressed between folds of blotting-paper; the residue again dissolved in ether, from which the margarine may now be obtained tolerably pure. It very much resembles stearine, but, as above-mentioned, has a lower melting point. It is rather doubtful if oleine has ever been prepared in a perfectly pure state, the separation of the last particles of margarine being very difficult. It may be obtained by subjecting olive oil to a freezing mixture, when the margarine will nearly all separate, and the supernatant fluid oil may be taken as oleine.

Oleine may also be procured by digesting the oils with a quantity of caustic soda, equal to one-half of what is requisite to saponify the whole; the stearine and margarine are first transformed into soap, then a portion of the oleine undergoes the same change, but a great part of it remains in a nearly pure state. This process succeeds only with recently-expressed or very fresh oils.

The fat oils are completely insoluble in water. When agitated with it, the mixture becomes turbid, but if it be allowed to settle the oil collects by itself upon the surface. This
method of washing is often employed to purify oils. Oils are little soluble in alcohol, except at high temperatures. Castor oil is the only one which dissolves in cold alcohol. Ether, however, is an excellent solvent of oils, and is therefore employed to extract them from other bodies in analysis; after which it is withdrawn by distillation.

Fat oils may be exposed to a considerably high temperature, without undergoing much alteration; but when they are raised to nearly their boiling point, they begin to be decomposed. The vapors that then rise are not the oil itself, but certain products generated in it by the heat. These changes begin somewhere under 600° of Fahr., and require for their continuance temperatures always increasing.

The products in this case are the same as we obtain when we distil separately the different constituents, (stearine, margaricine, &c,) that is to say, a little water and carbonic acid, some gaseous and liquid hydrocarbons, some solid fatty acids, (particularly margaric acid and some sebacic acid, provided by the decomposition of the oleine,) small quantities of the odoriferous acids, (acetic, butyric, &c,) and some acrolein. The acid and irritant odor which this last substance gives out especially characterizes the decomposition of fatty bodies by heat. It is produced from the glycerine only. If, instead of raising the heat gradually, we submit the fats or oils directly to a red heat, as by passing them through a red-hot tube, they are decomposed completely, and are almost entirely transformed into gaseous carburetted hydrogens, the mixture of which serves for illuminating purposes, and yields a far better light than ordinary coal gas. In places where the seed and fish oils can be procured at a low price, these substances might be employed with great advantage for this purpose.

**Action of Alkalies on the Oils.**—When the fats or oils are boiled with potash or soda, they are decomposed into glycerine and the fatty acids, with assimilation of water by both the glycerine and the fatty acids. Thus oleine yields glycerine and oleic acid, margarine, glycerine and margaric acid, and stearine, glycerine and stearic acid. The glycerine dissolves in the water and the fatty acids unite with the alkalies, forming soaps, (which see.) The action of ammonia on the oils is much less energetic: it, however, readily mixes with them, forming a milky emulsion, called volatile limenin, used as a rubefacient in medicine. Upon mixing water with this, or by neutralizing the ammonia by an acid, or even by mere exposure to the air, the ammonia is removed and the oil again collects. By the prolonged action of ammonia, however, on the oils, true ammoniacal soaps are formed, and at the same time a peculiar body is formed, called by its discoverer (Boullay) marmargamid. It corresponds exactly with the ordinary amides, its composition is \( \text{C}_4\text{H}_7\text{N}_2\text{O}_2 = \text{NH}_2\text{C}\left(\text{C}_4\text{H}_7\text{O}_2\right) \) or marmate of ammonia minus 2 equivalents of water.

\[
\text{NH}_2\text{C}\left(\text{C}_4\text{H}_7\text{O}_2\right) - 2\text{H}_2\text{O} = \text{NH}_2\text{O}(\text{C}_4\text{H}_7\text{O}_2)
\]

**Margareid.**

It is obtained by boiling the ammoniacal soap with water, when the magargamid or soap of the tannate combats the water on the top, and when allowed to cool solidifies. It is purified by solution in boiling alcohol, which deposits it again on cooling in the crystalline state. It is a white, perfectly neutral solid, insoluble in the air, insoluble in water, very soluble in alcohol and ether, especially by the aid of heat. It fuses at about 140° Fahr., and burns with a smoky flame. It is decomposed when boiled with potash or soda, forming true soaps, with the liberation of ammonia, and also by acids of a certain degree of concentration.

The alkaline carbides and some metallic oxides unite with the fatty acids, forming insoluble soaps, which in the case of lead is called a plaster.

After glycerine and the fatty acids have once been separated, they do not readily again unite; but Berthelot has succeeded in effecting this, by enclosing them for a considerable time in a sealed tube, and subjecting them to a more or less elevated temperature, when the true oils are again produced.

**Action of Acids upon the Oils.**—Sulphuric acid, (concentrated,) when added to the oils, unites with them energetically, the mixture becomes heated, and, unless cooled, chars with the liberation of sulphurous acid. When the mixture is cooled, the fats and oils undergo a similar change to that which the alkalies effect. There is formed some sulphoxylic acid, as well as combinations of margaric and oleic acids with sulphuric acid; these latter are again decomposed when mixed with water, liberating the fatty acids.

**Nitric acid** (concentrated) attacks the fatty bodies very rapidly, sometimes causing ignition. Dilute nitric acid acts less powerfully, forming the same compounds which we obtain by acting on the several constituents of the oils separately.

**Hyponitric acid, or nitrous acid,** converts the oleine of the non-drying oils into a solid fat, fistillate.

**Chlorine and bromine** act on the fatty oils, producing hydrochloric and hydrobromic acids, and some substitution compounds containing chlorine or bromine.

When moist chlorine gas is passed into the oils, the temperature rises, but it does not cause explosion. Bromine, on the contrary, acts with violence. The chlorine and bromine products thus obtained are generally of a yellow color, without taste or smell. They are heavier than water, and possess a greater consistence than the pure oils. Exposed to the air when slightly heated, they become considerably harder.
Iodine also attacks the oils, forming substitution compounds.

The fatty oils are divided into two classes, drying and non-drying oils, which are characterized by their different deportments when exposed to the atmosphere. In close vessels, oils may be preserved unaltered for a very long time, but with contact of the atmosphere they undergo progressive changes. Certain oils thicken and eventually dry into a transparent, yellowish, flexible substance, which forms a skin upon the surface of the oil and retards its further alteration. Such oils are said to be drying, or siccative, and are on this account used in the preparation of varnishes and painters' colors. Other oils do not dry up, though they become thick, less combustible, and assume an offensive smell. These are the non-drying oils. In this state they are called rancid, and exhibit an acid reaction, and irritate the fauces when swallowed, in consequence of the presence of a peculiar acid, which may be removed in a great measure by boiling the oil along with water and a little common magnesia for a quarter of an hour, or till it has lost the property of reddening litmus.

While oils undergo the above changes, they absorb a quantity of oxygen equal to several times their volume. Sanssuer found that a layer of nut oil, one quarter of an inch thick, enclosed along with oxygen gas over the surface of quicksilver in the shade, absorbed only three times its bulk of that gas in the course of eight months; but when exposed to the sun in August, it absorbed 60 volumes additional in the course of ten days. This absorption of oxygen diminished progressively, and stopped altogether at the end of three months, when it had amounted to 145 times the bulk of the oil. No water was generated, but 219 volumes of carbolic acid were disengaged, while the oil was transformed in an anomalous manner into a gelatinous mass, which did not stain paper. To a like absorption we may ascribe the elevation of temperature which happens when wool or hemp, besmeared with olive or rapeseed oil, is left in a heap; circumstances under which it has frequently taken fire, and caused the destruction of both cloth-mills and dockyards.

In illustration of these accidents, if paper, linen, tow, wool, cotton mats, straw, wood shavings, moss, or soot, be imbued slightly with linseed or hemspred oil, especially when wrapped or piled in a heap, and placed in contact with the sun and air, they very soon spontaneously become hot, emit smoke, and finally burst into flames. If linseed oil and ground manganese be triturated together, the soft lump so formed will speedily become firm, and ere long take fire.

Although most of the fixed oils and fats are mixtures of two or more of the substances oleine, margarine and stearine, yet there appears to be different modifications of these substances in drying and non-drying oils; for instance, it is only the oleine of the non-drying oils that solidifies when treated with nitrous acid or nitrate of mercury; and again the difference is shown in the fact of some oils drying completely, while others only thicken and become rancid.

A patent was taken out in May, 1819, by Messrs. Bessemer & Heywood, for a machine to be used for expressing oils from seeds. Fig. 467 is a drawing of it. The bedplate of

![Diagram](image-url)
bag \( v \), with open ends, formed of fustian, hair-cloth, or similarly pervious material, is made of such a diameter as will fit closely to the inside of the tube \( u \); and within this bag is placed a cylinder, \( w \), of wire gauze or finely perforated metal. The steel collar \( t \) is forced into the end of the wire gauze, by which it becomes driven into the recess formed at \( n \), and is securely held there by the pressure of the collar \( t \). The bag \( v \) and wire gauze \( w \) are then tightly stretched over the end \( n \) of the tube, and the collar \( u \) driven tightly on, by which means the bag and wire gauze are securely held in their places. The lining tube \( n \) is then put into the pressing cylinder as far as the shoulder \( g \). A tubular piece \( h \) is next put in and brought into contact with the collar \( n \), and then the gland \( i \) is screwed home, whereby the lining \( n \) is firmly retained within the pressing cylinder. The end of the pressing cylinder is contract at \( f^1 \), and forms a shoulder for the abutment of the collar \( j \), the diameter of the aperture in which regulates the pressure to which the matters under operation are subjected. Within the tube \( n \) there is fitted a solid plunger \( k \), which receives motion from the crank \( d \) by means of the connecting rod \( l \), the parallel motion being obtained by the wheels \( a \), on the cross-head \( o \), traversing on the side of the bedplate at \( a^4 \). \( x \) is a hopper, bolted to a flange \( f^2 \) on the pressing cylinder, and communicating therewith. There is also an opening in the tube \( n \) at \( n^1 \), corresponding with the opening into the hopper, so that any materials placed into the hopper may fall into the tube \( n \), when the plunger \( k \) is withdrawn from beneath the opening. At that part of the pressing cylinder which is occupied by the "lining," there are drilled numerous small holes, \( f^3 \), which communicate at various points with the spiral groove in the tube \( n \). On the outside of the pressing cylinder there are formed two collars, \( f^4, f^5 \), which abut against the projecting pieces \( e^1 \) and \( e^3 \), and cause the pressing cylinder to be retained firmly in its place. When steam-power is to be employed to give motion to the oil press, it is preferable to have the crank which is actuated by the steam piston, formed on the end \( d^1 \), on the crank-shaft of the oil press, and placed at such an angle to the crank \( d \), that when the crank \( d \) is pushing the plunger \( k \) to the end of its stroke, the steam piston will be at the half stroke, whereby the motive power applied will be the greatest at the time that the press offers the most resistance, and the steam piston also, when passing its dead points, will have to overcome the friction of the machinery only, as the plunger \( k \) will be in the middle of its back stroke. When any other motive-power is applied to turn the crank \( d \), it will be necessary to put a fly-wheel on the shaft \( d^2 \), as also such cog-wheels as will be necessary to connect it with the first mover. When this apparatus is to be employed in expressing linseed oil, the seed, after having been ground and treated in the way now commonly practiced, is put into the hopper, and motion being transmitted to the crank in the manner before described, the plunger \( k \) will commence a reciprocating movement in the tube \( n \) of the pressing cylinder. Each time that it reaches in the direction of the crank it will move from under the opening in the hopper, and allow a portion of the seed to fall into the tube, while the reverse motion of the plunger will drive it towards the open end of the cylinder, its passage being much retarded by the friction against the sides of the tube lining, but chiefly by the contraction of the escape aperture through the collar \( j \), which will produce a considerable amount of resistance, and consequently the plunger will have to exert an amount of pressure upon the seed in proportion as the escape aperture is made larger or smaller. The collar \( j \) is made movable, and by withdrawing the plunger entirely from the tube, it can be exchanged at any time for another having a larger or smaller opening. The lining may at any time be removed from the cylinder, and the worn parts removed when found requisite. The action of the plunger is somewhat like that of the plunger of a hydraulic press pump, the seeds being pumped in at one end of the pressing cylinder, and allowed to escape at the other, while the whole of the interior of the pressing cylinder that contains seed is lined with hair-cloth or other suitable pervious material, and, that it may be protected from injury, is covered with wire gauze or finely perforated metal. The bag is thus completely defended within, while it is supported at every part by the tube \( n \) on the outside, and is thus subjected to a very little wear and to no risk of bursting. The expressed oil, passing through the wire gauze and bag, finds its way through the perforation \( s \) into the spiral channel \( r \), and from thence it finds ready egress by the perforations \( f^2 \) in the pressing cylinder, and as it falls is received by the cistern \( a^5 \), from which it can be drawn by the pipe \( y \).

Two or more presses may be used side by side, actuated either by one crank throw or by separate throws upon one shaft, placed with reference to each other in such a manner as greatly to equalize the amount of resistance throughout the revolution of the crank shaft.

Although the one here described is a cylindrical pressing plunger, an angular section may be given to the pressing vessel and plunger, and may of course be used to express oils from any seeds containing them. In the drawing, no method is shown for heating the seed cake to be subjected to pressure therein, but as it is known to be desirable to heat some matters from which oil is to be expressed, the following method is described:—When heat is to be applied during the process of pressing, it is desirable to make the pressing cylinder of something larger diameter, and of greater length, and to divide the cistern \( a^5 \) into two separate compartments, over both of which the pressing cylinder is to extend; a strong wrought-
OILS.

iron tube is to enter the open end of the pressing cylinder, and to extend about half-way to the hopper, where it terminates in a solid pointed end; this tube is to occupy the centre of the pressing cylinder, and will consequently leave an annular space around it, which will be occupied by the seed, meal, or other matters under operation. Steam is let into this iron tube, and its temperature thereby raised to any desired point. The end of the tube which extends beyond the pressing cylinder is to be securely attached to a bracket projecting from the bedplate, so that it may be firmly held in its position, notwithstanding the force exerted against the pointed end of it. The effect of this arrangement will be, that as the seed, meal, &c., fall into the pressing cylinder and are pushed forward by the plunger, they will give out a portion of their oil in that state known as cold drawn, which will fall into the first compartment of the cistern a. The further progress of the meal along the pressing cylinder will bring it in contact with the pointed end of the heating tube; here it will have to divide itself, and pass along the annular space between the heating tube and the lining, and being thus spread into a thin cylindrical layer around the tube, it will readily absorb heat therewith, when a second portion of oil will be given out and received by the second compartment of the cistern; and thus will the operations of cold and hot pressing be carried on simultaneously.

Bessemer & Heywood's patent also mentions another machine for the expression of oils from the seeds, &c., by pressure in connection with water, or water rendered slightly alkaline. 'A sectional drawing of it is represented in fig. 468. A is a cast-iron cistern, having semicircular ends, and open on the upper side. At one end of it is fixed a cylindrical vessel, n, with hemispherical ends. This vessel is of considerable strength, and should be capable of withstanding a pressure of 5,000 pounds to the square inch. It is held in an upright position by a flange, turned upon it, and extending around one-half of its circumference. This flange rests upon a similar one formed around the upper side of the cistern a, and is bolted thereto. At the upper part of the vessel n is formed a sort of basin, n', the edge of which supports an arch-shaped piece of iron, n. At the centre of the basin there is an opening into the vessel, and a hydraulic cup-leather, r, is secured within the opening by means of the collar a. In the bottom of the vessel n there is also an opening, into which is fitted a cup-leather, n, secured in its place by the ring j, which is firmly bolted to the vessel n. A strong wrought-iron rod, k, extends from the top of the arch n, down through the vessel n, having two enlargements or bosses, k', k'', formed upon it, which are fitted to the cup-leathers. The upper part of rod k has a screw formed upon it at k', which passes through the boss k' and enters the boss k, in which a screw thread is formed. The boss k is provided with handles, r, by turning which the rod k may be raised or lowered when required. n is a pipe, through which water may be injected into the vessel n by a force-pump, such as is generally employed to work hydraulic presses. a is a cock, whereby a portion of the contents of the vessel n may be run off, and the pressure relieved when necessary. The two bosses, k' and k'', being of equal area, whatever pressure may be exerted within the vessel n, it does not tend to raise or lower the rod k, but such pressure, acting on the cup-leathers, will keep the joint tight, and prevent the matters under pressure from leaking out. After a certain quantity of oil or oleaginous matters have been expressed from vegetable or animal substances, the remaining portions which they contain are more difficult to obtain, and we therefore treat the oil in combination with the substances in which it is contained in the following manner:—The aforesaid substances, after coming from the oil-press or mill, are mixed with as much warm water, or water slightly impregnated with alkaline matter, as will reduce them to a semi-fluid state. They are then to be operated upon in the apparatus last described. For this purpose the handles r r are turned round, and the bosses k' withdrawn from its opening, while the boss k', which is much longer, will still close the lower aperture. The semi-fluid matters are then put into the basin n, and fall from thence into the vessel v, when it is fully charged the rod k is again lowered into the position shown in the figure. The communication with the hydraulic press pump is
then made by means of a cock attached to the pump, from which the water flows through the pipe into the vessel, and thus with a few strokes of the pump the whole of the contents of the vessel will be subjected to the requisite pressure. An interval of a few minutes is then allowed for the combination of the oil and water, and the cock is then opened, and a small portion of the fluid contents of the vessel allowed to escape into the cistern. The pressure being thus relieved, the handles *r r* are to be again turned so as to lift the rod *k* sufficiently high to withdraw the boss *k* from the lower opening; the contents of the vessel will then flow out into the cistern *l* and the boss *k*, being again lowered so as to close the lower aperture, the relling of the vessel may take place for another operation. The pressure thus brought upon the mixture of oleaginous matters and water will cause the oil therein contained to mix with the water, and form a milky-looking fluid, from which the oil may be afterwards separated from the water, either by repose in large vessels or by evaporating the water therefrom by heat. When the oil is to be used for soap-making, and some other purposes, this combination of oil and water may be used without such separation. When seed oil is the oil obtained, the mucilaginous matters assist in combining these fluids. After the materials have been drawn off from the cistern *l* and passed through a strainer, the solid portions are to undergo another pressing, in order to displace the remaining portion of their fluid contents. In some cases it will be found advantageous to boil up the milky-looking fluid resulting from the operation last described, in order to coagulate the albuminous portions and otherwise assist in the purification of the oil.

**Purification of oils.**—As the oils are obtained from the mills they generally contain some albuminous and mucilaginous matter, and some other impurities which require to be removed, in order to render the oil perfectly clear and fit for burning, &c. Several processes have been proposed for this purpose; the one most generally used is that known as Thénard’s process.

Although concentrated sulphuric acid acts so strongly on the oils, it is found that, when added only in small quantities, it attacks principally the impurities first. Thénard’s process consists in adding gradually 1 or 2 per cent. of sulphuric acid to the oil, previously heated to 100°, and well mixing them by constant agitation. To effect this, the process may be carried on in a barrel fixed on an axis and kept revolving, or in a barrel which is itself immovable, but having fixed in its axis a movable fan. After the action of the acid is complete, which is known by the oil, after twenty-four hours’ rest, appearing as a clear liquid, holding flocculent matter in suspension, there is added to it a quantity of water, heated to 140°, equal to about two-thirds of the oil; this mixture is well agitated until it acquires a milky appearance. It is then allowed to settle, when, after a few days, the clarified oil will rise to the surface, while the flocculent will have fallen to the bottom of the acid liquid. The oil may then be drawn off, but requires to be filtered to make it perfectly clear. The filtration is always a difficult matter, and is conducted in various ways. It is sometimes placed in tubs, in the bottom of which there are conical holes filled with cotton, but the holes become speedily choked with solid matters. Another and more speedy process is by the means of a displacing funnel, the apertures in the diaphragm being stopped with cotton.

Several patents have been taken out for the purification of oils. Some passing hot air through the oil while at the same time exposed to the action of light; others passing steam through the oil.

Cogon’s process is a combination of the latter with Thénard’s. He operates upon about 100 gallons of oil, and for this quantity he uses about 10 pounds of sulphuric acid, which he dilutes previously with an equal bulk of water. This acid mixture is added to the oil, placed in a suitable vessel, in three parts, the oil being well stirred for about an hour between each addition. It is then stirred for two or three hours in order to insure a perfect mixture, and thus let every particle of the oil be acted on by the acid. It then has assumed a very dark color. After being allowed to stand for twelve hours, it is transferred to a copper boiler, in the bottom of which are holes, through which steam is admitted, and, passing in a finely divided state through the oil, raises it to the temperature of 212°. This steam process is carried on for six or seven hours; the oil is then transferred to a cooler, having the shape of an inverted cone, terminating in a short pipe, provided with a stop-cock inserted in its side a little distance from the bottom. After being allowed to stand still the liquids are separated, which generally takes about twelve hours, the acid liquor is drawn off through the pipe at the bottom, and the clear oil by the stop-cock in the side of the cooler; all below this tap is generally turbid, and is clarified by subsidence or mixed with the next portion of oil.

Sometimes an infusion of nut-galls is used to separate the impurities, the tannic acid contained in which renders the impurities less soluble; the infusion is well mixed with the oil by agitation, and after separating the two liquids, the oil is deprived of any tannic acid it may have retained, by treating it with acetic of lead, or sulphate of zinc. When the oil is to be used for machinery it must be dried by treatment with freshly calcined sulphate of lime, or carbonate of soda.
OILS.

General Remarks on the Non-Drying Oils.

Olive oil.—Few vegetables have been so repeatedly noticed and so enthusiastically described by the ancient writers as the olive tree. It seems to have been adopted in all ages as the emblem of benignity and peace. The preserved or pickled olives, so admired as a dessert, are the green unripe fruit deprived of part of their bitterness by soaking them in water, and preserved in an aromatized solution of salt. There are several varieties not with in commerce, but the most common are the small French or Provence olive and the large Spanish olive. When ripe the fruit abounds in a bland fixed oil. The processes for extracting it have already been mentioned. Olive oil is a unctuous fluid, of a pale yellow or greenish yellow color. The best kinds have scarcely any smell; a bland and mild taste. In cold weather it deposits white or yellow globules (a combination of olein and micelline). It is soluble in about 13 times its weight of ether; but is only very slightly soluble in alcohol. By admixture with castor oil, its solubility in spirit seems to be increased. Pure olive oil has less tendency to become rancid than most other fixed oils, but the second qualities rapidly become rancid, owing probably to some foreign matters. It is not a drying oil, and is less apt to thicken by exposure to the air, and for this reason is preferred for greasing delicate machinery, especially watch and clock work. Brande describes a process for preparing it for these latter purposes. The oil is subjected to cold, when it principally solidifies; the portion, however, which still remains liquid is poured off from the solid portion. A piece of sheet lead, or some shot, are then placed in it, and it is exposed in a corked phial to the action of sunshine. A white matter gradually separates, after which the oil becomes clear and colorless, and is fit for use. Some oil prepared by this process kept its consistence very well for a century or more, and yet only took up a small part of the air. When exposed to the atmosphere it began to thicken, and did not answer so well as was expected by the watch-maker, who tried it from its appearance before exposure to the air.

The principal object in the process appears to be to get as pure oleine as possible, but the purer the oleine the more likely is it to become thick. According to Kerwyck, oleine of good quality can be obtained by mixing two parts of olive oil with one part of camphoric soda lye, and macerating the mixture for twenty-four hours, with frequent agitation. Weak alcohol must then be poured into it, to dissolve the margaritae soap, whereby the oleine, which remains unsaponified, is separated, and floats on the surface of the liquid. This being drawn off, a fresh quantity of spirit is added, till the separation of the oleine be complete.

It has a slightly yellowish tinge, which may be removed by digesting with a little animal charcoal in a warm place for twenty-four hours. By subsequent filtration, the oleine is obtained limpid and colorless, and of such quality that it does not thicken with the greatest cold, nor does it affect either iron or copper instruments immersed in it. There are four different kinds of olive oil known in the districts where it is prepared:—1. Virgin oil; 2. Ordinary oil (huile ordinaire); 3. Oil of the infernal regions (huile d'enfer); 4. Oil prepared by fermentation.

1) Virgin oil.—In the district Montpellier, they applied the term virgin oil to that which spontaneously separates from the paste of crushed olives. This oil is not met with in commerce, being all used by the inhabitants of the district either as an emollient remedy or for oiling the works of watches.

In the district of Aix, they give the name virgin oil to that which is first obtained from the olives ground to a paste in a mill, and submitted to a slight pressure two or three days after collecting the fruit. Thus, there is no virgin oil brought from Montpellier, but a good deal of it is brought from Aix.

2) Ordinary oil.—In the district of Montpellier, this oil is prepared by pressing the olives, previously crushed and mixed with boiling water. At Aix, the ordinary oil is made from the olives which have been used for obtaining the virgin oil. The paste, which has been previously pressed, is broken up, a certain quantity of boiling water is poured over it, and it is then again submitted to the press. By this second expression, in which more pressure is applied than in the previous one, an oil is obtained somewhat inferior in quality to the virgin oil. The oil is separated from the water in a few hours after the operation.

3) Oil of the infernal regions (huile d'enfer).—The water which has been employed in the preceding operation, is, in some districts, conducted into large reservoirs, called the infernal regions, where it is left for many days. During this period, any oil that might have remained mixed with the water separates, and collects on the surface. This oil being very inferior in quality, is only fit for burning in lamps, for which it answers very well. It is sometimes called lamp oil.

4) Fermented oil (huile fermentée).—This is obtained in the two above-named districts, by leaving the fresh olives in heaps for some time, and pouring boiling water over them before pressing the oil. But this method is very seldom put in practice, for the olives during this fermentation lose their peculiar flavor, become much heated, and acquire a musty taste, which is communicated to the oil.

The fruity flavor of the oil depends upon the quality of the olives from which it has been pressed, and not upon the method adopted in its preparation.
OILS.

There are met with in commerce, the virgin oil of Aix, the ordinary oil of Montpellier and Aix, rarely the oil by fermentation, and never the oil of the infernal regions.

When olive oil is mixed with nitric acid or nitrate of mercury, it solidifies after some time and forms a solid fat, of a light yellow color, which is called colidine. It is the oleine of the oil that is affected, and appears to undergo a molecular change, for the colidine is said to have the same ultimate composition as oleine itself.

Olive oil is used as food and in salads, hence is often called salad oil; and also in medicine in making ointments, &c., and for various other purposes.

The analyses of olive oil give the following results:—

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Owing to the high price of olive oil, it is frequently adulterated with oils of less value, as poppy oil, &c. This will be more fully treated of when speaking of the adulteration of oils in general.

Oil of almonds.—The tree (Amygdalus communis) which yields the almond, is a native of Syria and Barbary, but is now abundant throughout the south of Europe, and grows even in England, though here the fruit seldom ripens. The oil is obtained by expression from the bitter or sweet almonds, but mostly from the former, from the fact of their being cheaper, and the residual cake being more valuable, yielding by distillation with water the essential oil of almonds; when the presence of water is carefully avoided, the oil obtained from them is quite as good as that obtained from the sweet almonds; but when water is present with the almonds, as would be the case if they were deprived of their skins by maceration in water, the oil would possess a more or less acid taste. The average produce is from 48 to 52 lbs., from 1 cwt. of almonds (Pereira). When recently expressed it is turbid, but by rest and filtration becomes perfectly transparent. It possesses generally a slight yellow color, which becomes considerably paler by exposure to sunshine. It has a mild, bland taste, and little or no odor. It is less easily congealed by cold than olive oil. It speedily becomes rancid, and should be kept in well stoppered bottles. It is soluble in 25 parts of cold alcohol, and in 6 parts of boiling alcohol, and mixes in all proportions with ether. It is used for the same purposes as olive oil, in medicine, &c.; it is nutritious, but difficult of digestion; it is often used mixed with gum or yolk of egg as an emulsion.

Oil of almonds has the following composition:—

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Almond oil is sometimes adulterated with olive oil, poppy, and teel oil, and some commercial samples of oil seem to be only olive, mixed with a little almond oil.

Teel oil, or oil of sesameum.—The seeds which yield this oil are obtained from the Sesamum orientale, and are much esteemed in South Carolina, where they are called oily grain; and are made into soups and puddings, like rice. The fresh seeds yield a warm, pungent oil, which loses its pungency after a year or two, and is then used for salad; it is often mixed with olive oil for soups, &c.

Oil of Beech or Ben.—This oil is obtained by expression from the seeds of a plant (Moringa oleracea) indigenous to Arabia and Syria, and cultivated in the West Indies. It is colorless, or slightly yellow, without odor, and possesses a mild taste. It separates, by standing, into two parts, one of which bears a very low temperature without congealing. It is neutral to test paper, and becomes slowly rancid. It is used in the manufacture of some perfumes, to dissolve out the odoriferous principle of the flowers. See Perfumery.

By saponification it appears to yield two peculiar acids in small quantities, benic and moringic acids.

Beech oil.—The nuts of the beech tree (Fagus Sylvatica) yield about 12 per cent. of a clear oil, and 5 per cent. of a turbid oil. The clear oil is slightly yellow, without odor, and very thick. Its density at 60° F. is 9225. At 72° F. it becomes a yellowish mass. It is employed in cooking in France, and also for illuminating purposes.

The poor people of Silesia use this oil instead of butter.
OILS.

Oil of mustard.—The seeds of white mustard (Sinapis alba) yield about 36 per cent. of a yellow fatty oil, without odor, of a density of 9142 at 60° F., and does not solidify by cold. The seeds of the black mustard (Sinapis nigra) yield about 18 per cent. of a similar oil. It may be used for soups, &c.

Rape-seed oil.—This oil is prepared by expression from the seeds of several kinds of Brassica; the Brassica rapa yields about 33 per cent. of oil of sp. gr. 9128; and the Brassica rape a much smaller quantity of a similar oil of sp. gr. 9167. None but the driest seeds are used, and these are often subjected to heat in order to coagulate the albumen; but the oil, when first obtained, requires considerable purification before being fit for the purposes to which it is applied. Thénard's process, before mentioned, answers well. Dr. Rudolph Wagner has found that a solution of chloride of zinc may be advantageously substituted for sulphuric acid in the clarification of rape oil. The solution of the chloride used is of sp. gr. 1.93, and is used in the proportion of 14 per cent. of the crude oil. The mixture is then shaken, and at first the oil becomes yellow, then dark brown, and after a few days a dark brown deposit takes place. The oil is still turbid, but by adding hot water and passing steam through it, it is rendered clear, and the chloride of zinc separated.

Deutsh recommends to subject the rape oil to heat until it begins to decompose, and keep it in a state of gentle ebullition for a few hours; a scum forms and separates, and the oil becomes transparent and greenish. After two or three days' repose the clear oil is drawn off, and is fit for use.

Wurblon's method is to agitate the oil with a certain quantity of a solution of caustic soda, which dissolves the impurities, these separating with the small quantity of soap formed; the oil is afterwards well washed with water and collected.

Rape oil is of a light yellow color, peculiar taste and smell, which increase as the oil is heated. It is employed for illuminating, for the manufacture of soft soaps, for the oiling of wooden stuffs in the process of their manufacture, in the preparation of leather, and also for lubricating machinery.

The English rape-seed seems to yield the best oil.

Bottle of cacao.—This is obtained from the cacao nut, the seed of a tree (Theobroma cacao) which is largely cultivated in South America. The nuts yield about 50 per cent. of this substance, which is either expressed by the aid of heat, or by boiling the crushed seeds with water. It is yellowish, but may be obtained almost colorless by melting in hot water. It has the consistency of snail. It presents the odor and the taste of the cacao nut. Its density is 0.91; it fuses at 60° F., but does not solidify again till cooled to 73° F. It is composed in a great part of stearine, with very little oleine. It may be kept for a very long time without becoming rancid, and on this account it is sometimes used in pharmacy.

Plum kernel oil.—The kernels of the plum (Pruunus domesticae) deprived of their skin, yield about 33 per cent. of a transparent oil, of a brownish yellow color, and of a taste resembling that of oil of sweet almonds. Its sp. gr. is 0.9127; and solidifies at 16° F. It speedily becomes rancid. It is prepared especially in Wurtemburg, and is employed for lightening, for which it answers very well.

Coconut oil.—The trees (Cocos nucifera, &c.) which yield the coconut are natives of tropical climates, five varieties being indigenous to Ceylon. A powerful oil is extracted from the bark, and is used by the Cingalese as an ointment in cutaneous diseases. The coconut oil of commerce is obtained from the kernel of the nut. Two processes are used for its extraction in Malabar and Ceylon; viz., by pressure, aided by heat, or by boiling the bruised kernel with water, and skimming off the oil as it forms on the surface. It is a white solid, possessing a peculiar odor and mild taste. It fuses at about 70° F. It is composed principally of a peculiar fat, cocain, and a small quantity of oleine. It speedily becomes rancid. We receive it principally from South America. It is employed in the manufacture of candles and soap, and serves particularly for the manufacture of a marine soap, which forms a lather with sea-water. It is used largely in India and Ceylon as a pomatum, and is there prized for that purpose, but its speedily becoming rancid prevents its use here.

Palm oil.—This oil is extracted from the fruit of one of the palm trees, some say the Cocos butyracea, and others the Avorea elata. The oil resides in the fleshy portion of the fruit, which is about the size of pigeons' eggs, ovate, somewhat angular, deep orange yellow, collected in heads. They have a thin epicarp, a fibrous, oily, yellow sarcocarp, which covers and closely adheres to the hard stony putamen or codocarp, within which is the seed. The oil is obtained from the sarcocarp, and in this respect resembles the olive. It is obtained either by expression or by boiling the fruit with water, when the oil separates and rises to the surface. It is imported principally from Cayenne and the coasts of Guinea. It is, when freshly imported, of the consistence of tallow, of an orange color, and possesses the smell of violetas, and fuses at about 80° F. It speedily becomes rancid and decomposes with liberation of glycerine and the fatty acids, and as this change progresses, its fusing point gradually rises till it sometimes even reaches 97° F. It is composed principally of a peculiar fat, palmitin, and a little oleine and coloring matter. It is used in the manu-
OILS. 823

facture of soap and candles, and is imported in very large quantities. The following is a general outline of the treatment of palm oil at Price's Candle Company's works in 1835 (Pharm. J. Medic. J. 1835, 2, p. 466). The crude palm oil is melted out of the cake in which it has been imported, and allowed to remain in a melted state in large tanks until the mechanical impurities have settled to the bottom. The clear oil is then pumped into close vessels, where it is heated and exposed to the action of sulphuric acid. The glycerine and fatty acids are thereby separated, and the coloring matter and impurities are carbonized and partly rendered insoluble. The mixture has now a grayish-brown color, and is washed with water to remove the acid. From the washed product, distillation now separates the mixed fatty acids (palmitic and palm oleic acids), as a white crystalline fat, while the residuum in the still is converted into a fine hard pitch. This pitch is fit for any of the purposes to which ordinary pitch is applicable. The mixed fatty acids may be made directly into candles, or they may be separated by hydraulic pressure, aided, if necessary, by heat. This effects the separation of the liquid part (oleic acid), which, after purification, is fit for burning in lamps and other purposes. The hard cake left in the presses is nearly pure palmitic acid; it is brilliantly white, not at all greasy, and has a melting point of 135° to 138°. It is fit for the manufacture of the finest candles, either alone or in admixture with the stearine of the coconut oil.

Palm oil often requires to be bleached for its various uses, and there are several processes used to effect it, viz., chlorine, powerful acids, and the combined influence of air, heat, and light.

M. Pohl has bleached palm oil by heating it quickly to 464° F. and keeping it at that temperature for a few minutes, without the aid of light or air. And he says this process has been carried on for some time in a factory. The heating of the palm oil is effected as rapidly as possible in cases ten parts. It is kept for ten minutes at the temperature of 464° F., and the bleaching is complete. Ten or twelve hundred-weight of palm oil may be conveniently heated in one pan, which, however, must only be two-thirds full, as the oil expands greatly by the heat. It must be covered with a well fitted cover, which prevents inconvenience from the disagreeable vapors which arise. This answers better on the large scale than on the small. By this process it acquires an empyreumatic odor, which disappears after a little time, and the original odor of the palm oil returns.

The yellow fat which is used to grease the axle-trees of the railway carriages, is prepared with a mixture of palm oil and tallow, with which is mixed a little soda lye (Gerhardt's). For the properties of palmitic and palmitic acid see PALMITIC ACID.

Laurel oil.—This oil is known also under the name of "oil of bay," and is obtained from either the fresh or dried berries of the bay tree (Laurus nobilis), which grows principally in the south of Europe, and is also cultivated in our gardens, the leaves being used by the cook on account of their flavor. The berries were analyzed by Bonastre in 1824, and amongst other things, were volatile oil, 0.8, laurin (camphor of the bay berry), 1.9, and fixed oil, 12.8, in 100 parts of the berries. Duhamel states that the fixed oil is obtained from the fresh and ripe berries by bruising them in a mortar, boiling them for three or four hours in water, and then pressing them in a sack. The expressed oil is mixed with the decoction, and on cooling is found floating on the surface of the water. When the dried berries are used they are first subjected to the vapor of water until they are well soaked, and are then rapidly pressed between heated metallic plates. By the latter process they yield one-fifth of their weight of oil. It is imported in barrels from Trieste. It has a butyricaceous consisience and a granular appearance. Its color is greenish, and its odor like that of the berries. Cold alcohol extracts from it the essential oil and green coloring matter, leaving the lauro-stearine, which composes the principal part of it. With alkalies it forms soaps. But its principal use is in medicine, and more particularly in veterinary medicine. It has been used as a stimulating fluid in sprains and bruises, and in paralytics.

Native oil of laurel (Hancock); Laurel turpentine (Steinhou).—Imported from Demerara; obtained by incisions in the bark of a large tree, called by the Spaniards "Açote de susmijras," growing in the vast forests between the Orinoco and the Parina. This oil is transparent, slightly yellow, and smells like turpentine, but more agreeable, and approaching to oil of lemon. Its sp. gr. at 15° C is 0.93645. It consists of two or more oils isomeric with each other, and with oil of turpentine. Its color is due to a little resin. It is an excellent solvent for colchicine (Perisse). Ground-nut oil.—This is obtained from the fruit of the ground-nut plant (Arachis hypogea). Oestermer states, that a considerable quantity of the earth-nut having been imported into Bremen, without finding a market, the importers expressed the oil, which is sold under the name of earth-nut oil. According to Dr. Buchner, this plant belongs to the leguminosae, and the fruit is a nutted a whitish yellow, and four to nine lines thick, of which are contained two or three brownish-red ovoate seeds, of the size of a small hazel-nut. Their parenchyma is white, very nutritious and oily, on which account the Arachis, which is indigenous to the tropical parts of America, has been
transplanted to Asia and Africa, and even to the south of Europe; and is in that climate frequently cultivated and employed for the manufacture of the oil. The oily seeds possess a sweet taste, somewhat like that of haricot beans, and are used in tropical climates, partly raw, and partly prepared into a sort of chocolate, which, however, is not equal to that prepared from cacao. The oil is employed for the same purposes as olive oil. It is of a somewhat greenish color, and has a sp. gr. of 0.963 at 60° Fahr. It is only slightly soluble in alcohol (one part in 100). Its smell at ordinary temperatures is scarcely perceptible, but if heated to 122° or 107° Fahr. it acquires a smell like sweet oil, and the hardest beans, but is not disagreeable. Its taste is not quite so agreeable as that of almond oil and olive oil. Although not a drying oil, it does not solidify when treated with nitrous acid or nitrate of mercury, and by this also may be known from olive oil, &c.

Piney tallow.—This is prepared from the fruit of the Valeriana Lutea, a tree which grows in Malabar. It is obtained by boiling the fruit with water, and collecting the fat which rises to the surface. It is white, gummy to the touch, and of an agreeable odor. Its fusing point is at about 95°. It sp. gr. at 59° is 0.926, and at 95° 0.896. Alcohol extracts from it about 2 per cent. of oleine, possessing an agreeable odor. It answers well for the manufacture of soap and candles, but is little known in this country.

Spindle-tree oil.—The oil of spindle-tree (Euonymus Europaeus) is yellowish, rather thick, with the odor of olive oil, of a bitter and acid taste. It is solid at 5° Fahr. It gives to hot water a bitter substance. It is but little soluble in alcohol, and the solution has an acid reaction. It contains margarine, and oleine, and some benzoic and acetic acids.

Bitter of nutshell.—This is commonly known in the shops as an expressed oil of more, and is prepared by boiling the nutmeigs to a paste, placing them in a bag and exposing them to steam, and afterwards pressing between heated plates. It is imported in oblong cakes (covered by some leaves), which have the shape of common bricks, only smaller. It is of an orange color, firm consistence, fragrant odor, like that of nutmegs. Schroder found 16 parts of the oil, expressed by himself, contained 1 part of volatile oil, 6 parts of brownish yellow fat, and 9 parts of a white fat. The volatile oil and yellow fat are both soluble in cold alcohol and cold ether; the white fat soluble in alcohol and ether, when boiling, but insoluble in them when cold. By saponification it yields glycerine and myristic acid (C15 H30O2). A false article is sometimes made, composed of animal fat, boiled with powdered nutmegs, and flavored with sassafras (Pongamia). The genuine article may be known by being soluble in four times its weight of boiling alcohol, or half that quantity of boiling ether. Its principal use is in medicine. It must not be confounded with canola oil of more.

The Drying Oils.

Linseed oil.—The oil is obtained by expression from the seeds of the common flax (Linum usitatissimum), either with or without the aid of heat; the latter, being known as cold-drawn linseed oil, is better than that expressed by heat. By cold expression the seeds yield about 20 per cent. of oil, but by the aid of heat from 22 to 27 per cent. The cold-drawn oil is of a light yellow color, while that obtained by heat is brownish, and easily becomes rancid. It has a peculiar smell and taste. According to Sausure its sp. gr. is 0.935 at 52° Fahr.; 0.9125 at 122° Fahr.; and 0.8815 at 201° Fahr. At 4° Fahr. it becomes paler without solidifying; but at — 15° Fahr. it forms a solid mass. It is soluble in 5 parts of boiling alcohol, in 40 parts of cold alcohol, and in 1/6 parts of ether. It consists principally of a liquid oil, which differs, however, as before mentioned, from the oleine of olive oil and the non-drying oils in general, and is called linoleic, and yields by saponification, linoleic acid. It also contains some margarine, and generally some vegetable albumen and mucilage.

Pure linseed oil has the following composition:

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<tr>
<td>Caroon</td>
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<td>Hydrogen</td>
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<td>Oxygen</td>
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Linseed oil is easily saponified, yielding a mixture of oleate and margarate of the alkali, and a large quantity of glycerine, It is acted on rapidly by nitric acid, producing margaric acid, pimelic acid, and some oxalic acid. Chlorine and bromine act on it, yielding thick colored products. When linseed oil is heated in a retort, it gives off, before entering into ebullition, large quantities of white vapors, which condense to a limpid colorless oil, possessing the odor of new bread. As
soon as the ebullition commences these vapors cease; the oil froths up, and at length there is left a thick gelatinous residue, very much resembling caoutchouc.

The principal use of Linseed oil is in making paints and varnishes. It attracts oxygen rapidly from the air and solidsifies, and this property is what renders it so valuable for these purposes: it is the most useful of all the drying oils. The small quantities of vegetable albumen and mucilage which the oil naturally contains, appear, according to Liebig, to impair, to a certain extent, its drying properties, and the real object which is obtained by boiling these oils with litharge, or acetate of lead and litharge, is the removal of these substances; the oil then being brought more directly in contact with the oxygen of the atmosphere, dries up more rapidly. It was previously thought that some of the litharge was reduced to metallic lead, oxidizing at the same time some of the linoleine; but Liebig's opinion seems to be more likely to be correct. The boiling of the oil requires some little care. A few hundredths of litharge is added to the oil, or some use acetate of lead and litharge, and, as before stated, about an eighth part of resin; this is boiled with the oil, the scum removed as it forms, and when the oil has acquired a reddish color, the source of heat is removed, and the oil allowed to clarify by repose. Liebig thinks heat is not necessary, and his process for treating the drying oils, in order to increase their lucific properties, has already been mentioned. According to M. E. Barruel et Jean, the resublimation of the drying oils may be effected by the smallest quantities of certain substances, which would act in the manner of ferment. The boration of manganese acts in this way; a thousandth part of this salt being sufficient to determine the rapid desiccation of these oils.

Linseed oil is used in the manufacture of printers' ink; being heated in a vessel until it takes fire, it is allowed to burn some time, then it is tightly covered; and subsequently mixed with about one-sixth of its weight of lamp-black.

The thin gummed silks receive the last of their many layers with boiled linseed oil; it is also used for leather varnishes, and for oil-cloths.

The residue, after the expression of the oil from the seeds, is called oil-cake, and is sold for feeding cattle; that obtained from the English linseed is the best.

Walnut oil.—This is obtained by expression from the ordinary walnuts deprived previously of their skin, which are the produce of a tree (Juglans regia) which is a native of Persia, but cultivated in this country for the sake of the nuts.

When recently prepared it is of a greenish color, but by age becomes a pale yellow. According to M. Sausure its sp. gr. at 53° Fahr. is 0·9283, and at 201° Fahr., 0·9871. It has no odor and an agreeable taste. At 5° Fahr. it thickens, and at 17·5° Fahr. it forms a whitish mass. The nuts yield about 50 per cent. of oil, and it dries still more rapidly even than the linseed oil. It is principally used for paints and varnishes, and from its lighter color, it is often used for white paints.

Oil of the Hazel-nut.—This is extracted from the seeds of the Corylus avellana, which yield about 50 per cent. of the oil. It is liquid, has only a slight color, no odor, and a mild taste. Its sp. gr. at 59° Fahr. is 0·9212. At 14° Fahr. it solidifies.

Poppy Oil.—This is expressed from the seeds of the common poppy, (Papaver somniferum,) which grows wild in some parts of England. It is cultivated in very large quantities in Hindostan, Persia, Asia Minor, and Egypt, for the sake of the opium which is obtained from the capsules. It is cultivated in Europe for the capsules, which are used in medicine, or for the oil extracted from the seeds. The oil is obtained, by expression, from the seeds, which do not possess any of the narcotic properties of the capsules. These seeds are sold for bird's, under the name of mace-seed.

This oil resembles olive oil in its appearance and taste, and is often used to adulterate it. Its sp. gr. at 59° Fahr. is 0·9249. It becomes solid at 0° Fahr. It is soluble in 25 parts of cold alcohol, and in 6 parts of boiling alcohol, and may be mixed in all proportions with ether. It is used sometimes for lighting, and after treatment with litharge or subacetate of lead is used for paints.

Hempseed Oil.—The seeds of the common hemp (Cannabis sativa) yield, by expression, from 14 to 25 per cent, of their weight of a fixed oil. It is obtained principally from Russia, but the native places of the plant are Persia, Caucasus, and hills in the north of India. The seeds are small ash-colored shining bodies. They are demulcent and oleaginous, but possessing none of the narcotic properties of the plant. They are employed for feeding cage-birds, and it has been stated that the plumage of certain birds, as the bullfinch and goldfinch, becomes changed to black by the prolonged use of this seed. When fresh, this oil is greenish, but becomes yellow by age. It has a disagreeable odor, and insipid taste. It is soluble in all proportions in boiling alcohol, but requires 20 parts of cold alcohol to dissolve it. It thickens at 5° Fahr., and becomes solid at 17·5° Fahr. It is sometimes used for illuminating purposes, but being a drying oil, it forms a thick varnish, and thus clogs the wick; it is used also in making soft soap, and in paints. When boiled with litharge or subacetate of lead, it forms a good varnish.

Sunflower Oil.—The seeds of the sunflower (Helianthus annuus) yield about 15 per cent, of a limpid oil, having a clear yellow color; it has an agreeable odor, and mellowish
taste; its sp. gr. at 60° is .9263. At 9° Fahr. it becomes solid. It is sometimes employed as food, as well as for illuminating purposes, and for making soap.

**Castor Oil.**—The castor oil plant has been known from the remotest ages. Caillaud found the seeds of it in some Egyptian sarcophagi, supposed to have been at least 4,000 years old. Some people imagine it is the same plant that is called the gourd in Scripture. It was called κοράσιον by the Greeks, and ricinus by the Romans. It is a native of India, where it sometimes grows to a considerable size, and lives several years. When cultivated in Great Britain, it is an annual, seldom exceeding three or four feet. There appear to be several varieties of the ricinus; the official is the *Ricinus communis*, or *Poluta Chistis.* The seeds are oval, somewhat compressed, about four lines long, three lines broad, and a line and a half thick; externally they are pale gray, but marbled with yellowish-brown spots and stripes.

The oil may be obtained from the seeds by expression, by boiling with water, or by the agency of alcohol. Nearly all that is consumed in England is obtained by expression. In America the seeds cleansed from the dust and fragments of the capsules are submitted to a gentle heat, not greater than can be borne by the hand, which is intended to render the oil more liquid, and therefore more easily expressed. They are then submitted to pressure in a screw-press: the whitish oily liquid thus obtained is boiled with a large quantity of water, and the impurities skimmed off as they rise to the surface. The water dissolves the mucilage and starch, and the albumen is coagulated by the heat, forming a layer between the oil and water. The clear oil is now removed, and boiled with a very small quantity of water until aqueous vapor ceases to arise, and a small portion of the oil taken out in a phial remains perfectly transparent when cold. The effect of this operation is to clarify the oil, and to get rid of the volatile acid matter. Great care is necessary not to carry the heat too far, as the oil would thus acquire a brownish color and acid taste.

In the West Indies the oil is obtained by decoction, but none of it appears in commerce in this country.

In Calcutta it is thus prepared:—The fruit is sliced by women; the seeds are crushed between rollers, then placed in hempen cloths, and pressed in the ordinary screw or hydraulic press. The oil thus obtained is afterwards heated with water in a tin boiler until the water boils, by which means the mucilage and albumen are separated. The oil is then strained through flannel and put into canisters.

Two principal kinds of castor seeds are known, the large and the small nut; the latter yields the most oil, (Pereira.) The best East Indian castor oil is sold in London as "cold-drawn."

In some parts of Europe castor oil has been extracted from the seeds by alcohol, but the process is more expensive, and yields an inferior article.

Castor oil is a viscid oil, generally of a pale yellow color, a nauseous smell and taste. Its sp. gr. according to Saussure is 0·969 at 53° F. The acid taste which it sometimes possesses, may be removed from it by magnesia, (Gerhardt.) At about 0° F. it forms a yellow, solid, transparent mass. By exposure to the air, it becomes rancid, thick, and at last dries up, forming a transparent varnish. It dissolves easily in its own volume of absolute alcohol; castor oil and alcohol exercise a mutual solvent power on each other, (Pereira.) It is also equally soluble in ether.

Pereira states that there are chiefly three sorts of castor oil found in the London market; viz., the oil expressed in London from imported seeds, East Indian oil, and the American or United States castor oil. Castor oil is imported in casks, barrels, hogheads, and drummers. It is purified by decantation and filtration, and bleached by exposure to sunlight.

It is not quite decided how many kinds of fats castor oil contains; according to Gerhardt, several, but Saalmuller says only two. It is, however, principally composed of ricinoleic, with perhaps a little stearine and palmitine, and an acid resin. Its ultimate composition is shown by the following analyses:

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<td>Carbon</td>
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<td>Hydrogen</td>
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<tr>
<td>Oxygen</td>
<td>15·71</td>
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When castor oil is heated in a retort to 500° F., an oleaginous liquid distils over, without the liberation of much gaseous matter; about the third part of the oil thus passes over. If after this it is further heated, it froths up, but if the distillation is stopped before it begins to froth up, there remains in the retort a substance insoluble in water, alcohol, ether, the fatty and essential oils; this is treated with ether to remove any undecomposed castor oil, then dissolved in potash; the soap thus formed yields a fatty acid, viscid at ordinary temperatures, very soluble in absolute alcohol, but little soluble in weak spirit. The volatile products of the distillation contained oanathole, oanathylic acid, some acreolein, and solid fatty acids.
OILS.

Hypontric acid solidifies castor oil, and nitric acid when boiled with it converts it into cananthylic and suberic acids.

Castor oil is said to be adulterated sometimes with creton oil to increase its activity; this is a dangerous sophistication; it is also mixed with some cheap fixed oils. The latter adulteration has been said to be detected by the solubility of castor oil in alcohol, but unfortunately castor oil may contain as much as 33 per cent. of another fixed oil, and yet be soluble in its own volume of alcohol, (Pereira,) this oil possessing the property of rendering other oils soluble in spirit.

Grapeseed Oil.—The grappesones (Vitis vinifer'a) yield about 11 per cent. of their weight of a fixed oil, which, when fresh, of a clear yellow color, but becomes brown by age. It has an insipid taste, and little or no color. Its sp. gr. at 60° F. is 0.9202; at 3° F. it becomes solid. It is not of much value for illuminating purposes, but in some southern localities it is used for food.

Oil of the Pine and Fir Trees.—In the Black Forest in Germany, an oil is extracted from the cleaved seeds of the Pinus pinea and Pinus abies. It is limpid, of a golden yellow color, and resembles in smell and taste the oil of turpentine. Its sp. gr. is 0.935 at 60° F. It is very fluid and dries rapidly. It only conceals at —23° F. It answers well for the preparation of colors and varnishes.

Oil of Canellina.—This is extracted from the seeds of the Myrcrax sativas; it is of a clear yellow color, with but little smell or taste, and dries rapidly by exposure to the air. It is used for lighting.

The Oil of Belladonna Seeds.—This oil is extracted in Wurtzburg from the seeds of the Atropa belladonna, and is there used for lighting and cooking. It is limpid, of a golden yellow color, insipid taste, and no odor. All the poisonous principles of the plant are left in the seed-cake, which cannot, therefore, be given to cattle. The odor which is given off during its extraction, stupefies the workmen.

Oil of Tobacco Seeds.—The seeds of the Nicotiana tabacum yield about 31 per cent. of their weight of a drying oil, which is limpid, of a greenish-yellow color, and no odor. It does not possess any of the narcotic principles of the plant.

Cotton-seed Oil.—Many attempts have been made to render fit for use the oil obtained from the seeds of the cotton plant, (Gossypium Barbadense,) as immense quantities of these seeds are allowed to rot, or used only as manure upon the cotton lands of the south of the United States of America. When obtained by expression, the oil which runs from the press is of a very dark red color. It, however, deposits some of the coloring matter by standing, as well as a portion of semi-solid fat; and in cold weather this is precipitated in large quantities; and only partially redissolves again by increase of temperature. The great obstacle to the use of the oil thus obtained is its color, which appears to be derived from a dark resinous substance, presenting itself in small dots throughout the seed. These may readily be seen by examining a section of the seeds with a lens, or even with the naked eye, (Mr. Wayne, Pharmaceutical Journal, xvi. 335.) In bleaching, the oil loses from 10 to 15 per cent., a portion of which may be again recovered and used for making soap, for which purpose cotton-seed oil seems best fitted. It is a drying oil, and consequently not well fitted for machinery; and when burnt, rapidly clogs the wick. A very good soap for common purposes is made from it in New Orleans. Mr. Wayne also states, "that the oil, to be made profitably, should either be manufactured in the vicinity of the cotton plantation, as the seeds, from the attached fibre, are bulky, and the cost of transportation great; or the seed should be hulled at the spot, and shipped to the place where it is to be pressed. In that condition, as it requires three or four bushels of seed to produce one bushel of hulled seed ready for the mill. The hull and attached fibre are useful for paper stock; and the cake, left after the extraction of the oil, is nearly as valuable a food for cattle as that of linseed.

"It appears that boiling the crushed seeds with water yields a very bland, light-colored oil."

"The desire to bring this oil into use still exists, for a sample of it was sent a few months since from a merchant in America to a friend of mine to see if he could succeed in purifying it, which no doubt will ultimately be effected by some one."

The cotton plant grows principally in the south of the United States of America; but it has of late years been cultivated in India.

Croton Oil.—This oil is obtained from the seeds of the Croton Tiglii, by expression, or by the use of alcohol. It is a most violent purgative, and its only use is in medicine. (For a lengthened account of this oil, see Pereira's Materia Medica.)

ANIMAL OILS.

The mode of the formation of fats in animals has been explained upon two theories. That of Dumas, and supported by some high authorities, which considers that the fats are not formed in the animals, but that they receive the fat already formed from the vegetable kingdom, the herbarum obtaining it from the vegetables which serve them for food, and the
carnivora obtaining it from the herbivora on which they feed. No doubt some of the animal fats are thus obtained, but doubtless some are formed in the manner accounted for in the opposing theory of Liebig. He considers that the fat is formed principally by the decomposition of the amylaceous and saccharine matters taken in the food. These substances are principally consumed in respiration when the animal takes much exercise, being converted again into water and carbonic acid, from which they were formerly produced by the plants. When the animal is kept without exercise, the respiration is less vigorous, and if the animal at the same time be fed with these amylaceous or saccharine substances, the excess of these is converted into fat.

Huber of Geneva, several years since, found that bees did not obtain their wax entirely from plants; he kept some bees in a confined place and fed them entirely on honey, and they formed quite as much wax as when they were perfectly at liberty amongst the flowers; in this way he proved that wax, which is a true fat, was a secretion of the bee. See Nutrition.

The only oils which will be mentioned here arelard oil, tallow oil, and neat's-foot oil.

Lard Oil.—This oil is now imported largely from America, and is obtained by subjecting ordinary hog's-lard to pressure, when the liquid part separates, while the lard itself becomes much harder. It is employed for greasing wool, for which purpose it answers very well, and may be obtained at a low price. According to Braconnet, lard yields 0.62 of its weight of this oil, which is nearly colourless. Sp. gr. 0.915, (Cheval.) 100 parts of boiling alkaid dissolve 123 parts of it.

Tallow Oil.—This oil is obtained from tallow by pressure. The tallow is melted, and when separated from the ordinary impurities by sub stance, is poured into vessels and allowed to cool slowly to about 80°, when the scarine separates in granules, which may be separated from the liquid part by straining through flannel, and is then pressed, when it yields a fresh portion of liquid oil. It is employed in the manufacture of some of the best soaps.

Neat's-foot Oil.—After the hair and hoofs have been removed from the feet of oxen, they yield, when boiled with water, a peculiar fatty matter, which is known under the name of Neat's-foot oil; after standing, it deposits some solid fat, which is separated by filtration; the oil then does not congeal at 32°, and is not liable to become rancid. It is often mixed with some of these. This oil is used for various purposes, especially, owing to its remaining liquid at so low a temperature, for oiling church clocks, which require, in consequence of the cold they are exposed to, an oil which is not liable to solidify.

FISH OILS.

Although the whale is not, truly speaking, a fish, the oil obtained from it is classed among the fish oils, and those which will be described here are, whale oil, porpoise oil, seal oil, and cod-liver oil. The three former are all known under the name of train oil.

Whale Oil.—The capture of the whales is a large commercial undertaking; many well-named ships, and fitted out at great expense, proceed every year from England, Holland, France, and other nations, into the arctic zone in search of these animals, and especially the Greenland species, (Balena mysticetus.) This valuable animal has produced to Britain £700,000 in one year, and one cargo has been known to be worth £11,000. The Greens land whale inhabits the polar seas; its length is from 60 to 70 feet, when full grown. When the whales are captured they are secured alongside the ship, and the processes of fleshing commences. The men, having shoes armed with long iron spikes to maintain their footing, get down on the large and slippery carcass, and with very long knives and sharp spades make parallel cuts through the blubber, from the head to the tail. A band of fat, however, is left around the neck, called the kent, to which hooks and ropes are attached for the purpose of shifting round the carcass. The long parallel strips are divided across into portions weighing about a ton each, and being separated from the flesh beneath are hoisted on board, chopped into pieces, and put into casks. During the homeward voyage the animal matters, &c., attached to the blubber, undergo decomposition to a certain extent, while there is at the same time a peculiar fat formed, which is a compound of glycerine and phocene acid, and which imparts the disagreeable odor peculiar to train oil. Dumas has shown that this acid is identical with valeric acid. After the decomposition of the blubber, the oil runs from it easily, and the whole is put into casks with perforated bottoms, placed over tanks for receiving the oil. The oil is heated to about 212°, to facilitate the separation of the impurities, and in order to further purify it, some use a solution of tannin, to precipitate the gelatine present; others use different metallic salts, as acetate of lead. On the western coast of Ireland the whale is sometimes captured, and yields a large quantity of very good oil, superior to sperm oil for illuminating purposes. The sperm whale (Physeter macrocephalus) does not yield so much oil as the Greenland whale, but yields considerably more of the valuable substance spermaceti.

Train oil is of a brownish color, with a disagreeable odor; it is used for lighting, in the manufacture of soft soaps, and in the preparation of leather.

Referring to the American whale fishery for 1859, the Peterhead Sentinel says: "The
result is not so satisfactory as we had anticipated; indeed, it will be seen that there are indications of a gradual decline. Going back seven years, we find that the number of vessels was nearly 670; on the 1st of January, 1869, it was only 571, showing a decrease as compared with the previous year of 34 vessels, with an aggregate of 18,065 tons; and it is calculated that there will be as great a falling off during the current year. The whole imports of 1859 were as follows:—Sperm, 9,141 tons; whale, 19,041 tons; bone, 1,928,850 lbs. From this it appears that there has been an excess over the year 1858 in sperm of 916 tons; whale, 819 tons; and in bone, 223,250 lbs. The exports of oil and bone were, sperm, 2,221 tons; whale, 818 tons; and bone, 1,707,929 lbs. This shows that the export of sperm oil in 1859 largely exceeds that of 1858, while that of the whale has been light. As regards prices, the average of whale oil was, in 1858, 2s. 3d., and in 1859, 2s. 0½d. per gallon. During the same periods the prices in this country were respectively 2s. 9d. and 2s. 5d. per gallon. In America, sperm oil, in 1858, was 5s. 5d., and in 1859, 5s. 8d. per gallon, against 5s. to 8s. in this country.

**Sail Oil.**—The seal-fishery of Newfoundland has now become the most important part of the trade of that colony. Although not perhaps so extensive a staple as the cod-fishery, yet when capital and time employed, &c., are taken into consideration, it is the most profitable business of that colony, or perhaps of any other part of the British empire. A quarter of a century ago, there were only about 50 vessels, varying from 30 to 60 tons burden, engaged in this branch of trade; but it has since been gradually increasing. In the year 1850, the output for this fishery from Newfoundland consisted of 229 vessels of 20,581 tons, employing 7,919 men. The number of seals taken was 440,828. According to the custom-house returns for that year, the total value of skins and oils produced from the seal amounted to £298,796. In the year 1852, the outfit consisted of 307 vessels of 55,700 tons, employing about 13,000 men. There were from half to three-quarters of a million seals captured.

The vessels engaged in this business are from 75 to 200 tons burden. Those lately added to the sailing fleet, and which are now considered of the most suitable sizes, range from 130 to 160 tons. Vessels of this size carry from 40 to 50 men. The season of embarking for this voyage is from the 1st to the 15th of March. The voyage seldom exceeds two months, and is often performed in two or three weeks. Several vessels make two voyages in the season, and some perform the third voyage within the space of two months and a half.

The seals frequenting the coast of Newfoundland are supposed to whelp their young in the months of January and February; this they do upon pans and fields of ice, on the coast, and to the northward of Labrador. This ice—or the whelping-ice, as it is termed—from the currents and prevailing northerly and north-east winds, trends towards the east and north-east coast of Newfoundland, and is always to be found on some part of the coast after the middle of March, before which time the seals are too young to be profitable.

The young seal does not take to the water until it is three months old. They are often discovered in such numbers within a day's sail of the port, that three or four days will suffice to load a vessel with the pelts, which consist of the skin and fat attached, this being taken off while the animal is warm; the carcass, being of no value, is left on the ice. The young seals are accompanied by the old ones, who take to the water on the approach of danger. When the ice is jammed, and there is no open water, large numbers of the old seals are shot. The young seals are easily captured; they offer no resistance, and a slight stroke of a bat on the head readily despatches them. When the pelts are taken on board, sufficient time is allowed for them to cool on deck. They are then stowed away in bulk in the hold, and in this state they reach the market at St. John's and other ports in the island. Five-sevenths of the whole catch reach the St. John's market. A thousand seal skins are considered as a remunerating number; but the majority of the vessels return with upwards of 3,000, many with 5,000 and 6,000, and some with as many as 7,000, 8,000, and 9,000. Seals were formerly sold by tale; they are now all sold by weight—that is, so much per cwt. for fat and skin.

The principal species captured are the hood and harp seal. The bulk of the catch consists of the young hood and harp in nearly equal proportions. The best and most productive seal taken is the young harp. There are generally four different qualities in a cargo of seals, namely, the young harp, young hood, old harp and bedlamier, (the latter is the year-old hood,) and the old hood. There is a difference of 2s. per cwt. in the value of each denomination.

The first operation after landing and weighing is the skinning, or separating the fat from the skin; this is speedily done, for an expert skinner will skin from 300 to 400 young pets in a day. After being dry-salted in bulk for about a month, the skins are sufficiently cured for shipment, the chief market for them being Great Britain. The fat is then cut up and put into the small vats.

The seal-fat consists of what are termed the crib and pan. The crib is a strong wooden erection, from 20 to 30 feet square, and 20 to 25 feet in height. It is firmly secured with iron clamps, and the intertactions between the upright posts are filled in with small round
OILS.

It has a strong timber floor, capable of sustaining 300 or 400 tons. The crib stands in a strong wooden pan, 3 or 4 feet larger than the square of the crib, so as to catch all the drippings. The pan is about 3 feet deep, and tightly caulked. A small quantity of water is kept on the bottom of the pan, for the double purpose of saving the oil in case of a leak, and for purifying it from the blood and any other animal matter of superior gravity. The oil made by this process is all cold-drawn; no artificial heat is applied in any way, which accounts for the unpleasant smell of seal oil. When the fats begin to run, the oil drops from the crib upon the water in the pan; and as it accumulates it is casked off, and ready for shipment. The first running, which is caused by compression from its own weight, begins about the 10th of May, and will continue to yield what is termed pale seal oil, from two to three months, until from 50 to 70 per cent. of the quantity is drawn off, according to the season, or in proportion to the quantity of old seal fat being put into the vats. From being tougher, this is not acted upon by compression, nor does it yield its oil until decomposition takes place; and hence it does not, by this process, produce pale seal oil. The first drawings from the vats are much freer from smell than the latter. As decomposition takes place, the color changes to straw, becoming every day, as the season advances, darker and darker, and stinking worse and worse, until it finally runs brown oil. As this running slackens, it then becomes necessary to turn over what remains in the vats. The oil being generally divided into nine departments or pounds, this operation is performed by first emptying one of the pounds, and dispersing the contents over the others, and then filling and emptying them alternately until the entire residue, by this time a complete mass of patredication, is turned over. By this process a further running of brown oil is obtained. The remains are then finally boiled out in large iron pots, which, during the whole season, are kept in pretty constant requisition for boiling out the cuttings and clippings of the skinning and other parts of the pelts, which it is not found advisable to put into the vats. The produce of this, and the remains of the vats, are what is termed the boiled seal oil. These operations occupy about six months, and terminate towards the end of September.

During the months of July, August, and September, the smell and effluvia from the vats and boiling operation are almost inaudible. The healthy situation of St. John’s, from its proximity to the sea, and the high and frequent local winds, is doubtless the cause of preventing much sickness at this season of the year. The men more immediately employed about the seal-vats have a healthy and vigorous appearance.

Some improvement has taken place since the great fire of 1846, when all the seal-vats in the town were destroyed. Many of the manufacturers have erected their new vats on the south or opposite side of the harbor; but there still remain sufficient vestiges of the seal trade to cause a summer residence in the town of St. John’s any thing but desirable. Even the country for several miles around St. John’s affords no protection from these horrible stenches. The animals remains from the vats, and the offal from the cod-fish, are found to be such a valuable manure, that they are readily purchased by the farmers in the neighborhood; and from whatever quarter the wind blows, the pedestrian in his rural walk has little chance of breathing a genial atmosphere.

Mr. S. G. Archibald directed his attention to some mode of improving the manufacture of the seal oil. The result of several experiments upon the different qualities of seal’s fat satisfied him that the whole produce of the fishery, if taken while the material is fresh, as it generally gives in the market, and subjected to a process of artificial heat, was capable of yielding, not only a uniform quality of oil, but the oil so produced was much better in quality than the best prepared by the old process, and free from the unpleasant smell common to all seal oil. His subsequent experiments resulted in the invention of a steam apparatus for rendering seal and other oils, which has been found to answer an admirable purpose, and for which he received letters-patent under the Great Seal of the Island of Newfoundland.

The advantage of this process must be manifest, when it is understood that twelve hours suffice to render the oil, which by the old process requires about six months; that a uniform quality of oil is produced superior to the best pale by the old process, and free from smell; that a considerable percentage is saved in the yield, and what is termed pale seal, produced from the old as well as from the young seal. Besides, if this process were universally adopted, the manufacturing season would cease by the 31st of May, and the community would be saved from the annoyance attending the old process.

The chief market for seal oil and skins has hitherto been Great Britain and Ireland; a few cargoes occasionally go to the Continental cities.

In the United States the greatest consumption of oil is for domestic purposes. Candles, unless of the most expensive kind, will not suit that climate, particularly in the summer season; and hence oil and camphene, where gas is not used, are the chief ingredients for lamps. All animal oils used in that country, whether of sperm, right whales, or herring, are rendered by artificial heat, and in consequence free from the unpleasant smell of our cold-drawn seal oil.

Purpoise Oil.—This oil very much resembles whale oil.

Cockler Oil.—This oil is obtained principally from the livers of the common cod, (Cul—
larias; Gades Morrhua,) previously called Azelius major, and also from some allied species, as the Dorso, (Gades callarias; the Coal Fish, (Merlangius carbonarius;) the Burbot, (Lota vulgaris;) the Linge, (Lota molon,) and the Torsh, (Brosiures vulgaris.) The mode of preparing this oil varies in different countries; that found in the London market is the produce of Newfoundland, where, according to Pennant, it is thus procured:—Some spruce boughs are pressed hard down into a half tub, having a hole through the bottom; upon these the livers are placed, and the whole exposed to the sun. As the livers become decomposed the oil runs from them, and is caught in a vessel placed under the tub. De Jongh describes three kinds of cod-liver oil—the pale, pale brown, and brown.

Pale Cod-liver Oil.—This is golden-yellow; without disagreeable odor; not bitter, but leaves a peculiar acid, fishy taste in the mouth; has a slight acid reaction; sp. gr. 0'925 at 63° F. Cold alcohol dissolves from 2°5 to 2°7 per cent. of the oil; hot alcohol from 3°5 to 4 per cent. It is soluble in ether in all proportions.

Pale Brown Cod-liver Oil.—Color of Malaga wine; odor not disagreeable; bitterish, leaving an acid, fishy taste in the throat; reacts feebly as an acid; sp. gr. 0'924 at 63° F. A little more soluble in alcohol than the pale oil.

Dark Brown Cod-liver Oil.—This is dark brown, and by transmitted light is greenish; it possesses a disagreeable odor, bitter and empyreumatic taste, which remains some time in the fauces; it is slightly acid; sp. gr. 0'929 at 63° F. Still more soluble in alcohol than the pale brown oil.

Cod-liver oil is principally used in medicine; for a fuller description of it, see Pereira's Materia Medica.

Dugong Oil.—This oil has been used instead of cod-liver oil, principally in Australia; but as very little, if any, real Dugong oil has reached England, it will merely require a short notice here. The Dugong is an animal belonging to the class of herbivorous cetaceans, and is found on the northern coast of Australia, in the Red Sea, the Persian Gulf, and also in the Indian seas. It has received different names by different nations. In the Indian seas it is sometimes found of a large size, from 18 to 20 feet long but; in Australia it is seldom caught of more than 12 or 14 feet. In its general form it resembles the common whale. Its favorite haunts are the mouths of rivers and straits between proximate islands, where the depth of water is but trilling, (3 or 4 fathoms,) and where, at the bottom, grows a luxuriant pasturage of submarine algae and fuel, on which it feeds. The oil is obtained by skimming the animal and then boiling down the "speck." It was used by the natives of Australia originally for burning.

Adulteration of the Oils.—Owing to the large quantities of oil of various kinds which are now used, and their difference in price, many are the adulterations which take place. Thus the best olive oil for the table is mixed with oils of less value, as poppy oil, sesame oil, or ground-nut oil; and the second olive oil, for the manufacturers, with colza oil; and again colza oil itself mixed with poppy, camellia, and linseed oils, but more frequently with whale oil, &c. Various means have been proposed to discover these admixtures. M. Lefebvre proposed to take advantage of the difference of density of the several oils, but this is a very insufficient test, as many of the oils have nearly the same density. M. Pontet treats the oil to be tested with one-twelfth of its weight of a solution of nitrate of mercury, containing lyponitic acid; this latter substance converts the oil into most of the non-drying oils into a solid substance, daitaine. By this means pure olive oil will become perfectly solid after an hour or two, whereas poppy oil and the drying oils in general remain perfectly liquid; it would therefore result that olive oil, adulterated with these latter oils, would be prevented from solidifying more or less, according to the quantity of these oils present. An improvement in this process is to substitute nitric acid, saturated with hypnitratic acid, for the nitrate of mercury solution. The sample to be tested is shaken with two or three per cent. of this acid, and then placed in a cool place, and the moment of solidification noticed. It is always better also to treat a sample of oil of known purity to the same test at the same time, and compare the results. If the sample tested be pure, it will solidify quite as quickly as the sample which serves for comparison. One hundredth of poppy oil present will delay the solidification 40 minutes, (Gerhardt,) and of course the greater the quantity of admixture, the more will it be delayed.

M. Maunzée takes advantage of the greater amount of heat given out by the admixture of concentrated sulphuric acid with the drying oils, than takes place with olive oil under the same circumstances. MM. Heydenreich and Penot employ sulphuric acid also to detect the different oils, but they notice the peculiar colorations which take place on contact of the concentrated acid with the different kinds of oils. Their test is thus performed:—One drop of concentrated sulphuric acid is added to 8 or 10 drops of the oil, placed on a piece of white glass, resting on a sheet of white paper; different colorations appear, which they state are characteristic of the different oils; thus olive oil gives a deep yellow tint, becoming greenish by degrees; colza oil a greenish blue; poppy oil, a pale yellow tint, with a dirty gray outline; hempsed oil, a very deep emerald tint; and linseed oil becomes brownish red, passing directly into blackish brown, &c. These reactions are, however, uncertain; the age of the oil, mode of extraction, &c., altering them greatly.
Marchand states that a mixture of poppy oil and olive oil, when thus treated, develop, after a certain time, on their outline, a series of colors, rose, lilac, then blue, and more or less violet-colored, according to the proportion of poppy oil, while pure olive oil becomes of a dirty gray, then yellow and brown.

As the means of detecting the various fraudulent admixtures is of great commercial value, I shall conclude by giving the heads of J. C. Calvert's valuable paper on the adulteration of oils, (Pharmaceutical Journal, xiii. 356.) He there recommends that samples of pure oil should always be tested comparatively with those suspected of being adulterated, and never to rest contented with only one of the tests mentioned.

As the reactions presented by the various oils depend upon the special strength and purity of the reagents, not only should great care be taken in their preparation, but also in the exact mode and time required for the chemical action to become apparent. These points will be described with each reagent.

**Solution of Caustic Soda, sp. gr. 1.340.**

The reactions given in the following table are obtained by adding one volume of this test-liquor to five volumes of oil, well mixing them, and then heating the mixture to its point of ebullition.

<table>
<thead>
<tr>
<th>Dark Colorations</th>
<th>Light Colorations</th>
</tr>
</thead>
</table>
| Sperm Seal Cod-liver | thick brown-yellow fluid | Neat's foot | dirty yellow | Pale rapeseed
| red | | lowish white | Poppy | yellow |
| Linseed | | pinkish white | French nut | white |
| | | white | Castor | |
| | | white | India-nut (thick) | white |
| | | | Gallipoli | yellow |
| | | | Olive | |

The principal use of this table is to distinguish fish from animal and vegetable oils, owing to the distinct red color which the former assume, and which is so distinct that one per cent. of fish oil can be detected in any of the others. Hempseed oil also becomes brown-yellow, and so thick that the vessel containing it may be inverted, for an instant, without losing any of its contents, whilst linseed oil acquires a much brighter yellow color, and remains fluid. India-nut oil is characterized by giving a white mass, becoming solid in five minutes after the addition of the alkali, which is also the case with Gallipoli and pale rape oils, while the others remain fluid.

The next test he uses is dilute sulphuric acid, and as the reactions vary with the strength of the acid, he employs three different strengths.

**Sulphuric Acid of sp. gr. 1.475.**

The mode of applying this acid consists in agitating one volume with five volumes of oil until complete admixture, and after standing fifteen minutes the appearance is taken as the test reaction.

<table>
<thead>
<tr>
<th>Not Colored</th>
<th>Colored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lard, dirty</td>
<td>India-nut</td>
</tr>
<tr>
<td>Pale rape-seed</td>
<td></td>
</tr>
<tr>
<td>Poppy</td>
<td></td>
</tr>
<tr>
<td>Castor</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The most striking reactions in this table are those presented by hempseed and linseed oils, for the green coloration which they acquire is such, that if they were used to adulterate any of the other oils, they would be immediately detected if only present to the amount of ten per cent. The red color assumed by the fish oils with this test is also sufficiently marked to enable us to detect them in the proportion of one part in 100 of any other oil, and it is at the point of contact of oil and acid, when allowed to separate by standing, that the red color is principally to be noticed.
**OILS.**

*Salphuric acid, sp. gr. 1-835.*

One volume of this acid is mixed, as before, with five volumes of oil and allowed to stand five minutes.

<table>
<thead>
<tr>
<th>Light Colorations</th>
<th>Marked Colorations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lard - { dirty white.</td>
<td>Olive - { greenish white.</td>
</tr>
<tr>
<td></td>
<td>dirty white.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As hempeaseed, linseed, fish, Gallipoli, and French nut oils are the only ones that assume with the above reagent a decided coloration, they can be discovered in any of the others.

*Salphuric acid of sp. gr. 1-635.*

This acid is used in a similar manner to those above, and the coloration noted after two minutes.

<table>
<thead>
<tr>
<th>Not Colored.</th>
<th>Distinctly Colored.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poppy.</td>
<td>Sperm - { intense</td>
</tr>
<tr>
<td>Sesame.</td>
<td>Seal - { brown.</td>
</tr>
<tr>
<td>Castor.</td>
<td>Cod-liver - {</td>
</tr>
</tbody>
</table>

The colorations produced by sulphuric acid, sp. gr. 1-635, are so marked, that they may be consulted with great advantage in many cases of adulteration: for example, Mr. Calvert has been enabled to detect distinctly ten per cent. of rape-seed in olive oil, of lard oil in poppy oil, of French nut oil in olive oil, of fish oil in neat's-foot oil.

This appears to be the maximum strength that can be used, for nearly all the oils begin to carbonize, and their distinct coloration to be destroyed.

Action of nitrile acid, of different strengths, on oils:

*Nitric acid of sp. gr. 1-180.*

One part of this acid, by measure, is agitated with five parts of oil, and the appearance, after standing five minutes, is described in this table.

<table>
<thead>
<tr>
<th>Not Colored.</th>
<th>Colored.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish.</td>
<td>Animal.</td>
</tr>
<tr>
<td></td>
<td>Olive -</td>
</tr>
<tr>
<td></td>
<td>French nut -</td>
</tr>
<tr>
<td>Not Colored.</td>
<td>Colored.</td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>Cod-liver.</td>
<td>Lar'd.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The chief characters in the above table are those presented by hempseed, sesame, French nut, poppy, and seal oils, and they are such that they not only may be employed to distinguish them from each other, but are sufficiently delicate to detect their presence when mixed with other oils, in the proportion of 10 per cent.

**Nitric acid of sp. gr. 1.330.**

One part of this acid is mixed with 5 parts of oil by measure, and remains in contact 5 minutes.

<table>
<thead>
<tr>
<th>Not Colored.</th>
<th>Colored.</th>
</tr>
</thead>
<tbody>
<tr>
<td>India nut.</td>
<td>Sperm</td>
</tr>
<tr>
<td>Pale rape-seed.</td>
<td>Seal</td>
</tr>
<tr>
<td>Castor.</td>
<td>Cod-liver</td>
</tr>
</tbody>
</table>

The colorations here described are very marked, and can be employed with advantage to discover several well-known cases of adulteration: for instance, if 10 per cent. of sesame or French nut oil exists in olive oil; but the same proportion of poppy oil cannot be thus detected, as the color produced is not so intense as in the other cases. But if any doubt remains in the mind of the operator, as to whether the adulterating oil was sesame, French nut, or poppy, he would be able to decide it by applying the test described in the next table, where he will find that French nut oil gives a fibrous semi-saponified mass, sesame a fluid one, with a red liquor beneath, and poppy, also a fluid mass, but floating on a colorless liquid.

The successive application of nitric acid of sp. gr. 1.330, and of caustic soda of sp. gr. 1.340, can be also successfully applied to detect the following very frequent cases of adulteration: first, that of Gallipoli with fish oils, as Gallipoli oil assumes no distinct color with the acid, and gives with a soda a mass of a fibrous consistency, whilst fish oils are colored red, and becomes mucilaginous with the alkali.

Secondly, that of castor oil with poppy oil, as the former acquires a reddish tinge, and the mass with the alkali loses much of its fibrous appearance.

Thirdly, unpressed oil with French nut oil, as nitric acid imparts to the former a more or less intense red tinge, which an addition of the alkali increases, and renders the semi-saponified mass more fibrous.

Mr. Calvert here remarks that the coloration which divers oils assumes under the influence of the three test nitric and sulphuric acids, clearly show that the reason why chemists had not previously arrived at satisfactory results in distinguishing oils in their various adulterations, was that the acids they employed were so concentrated that all the distinctive colorations were lost; the oils became yellow or orange; but there is no doubt that the above reagent will enhance the value of Mr. P. Baudet's, as they afford very useful data to specify the special oils mixed with olive oil.

**Caustic soda of sp. gr. 1.344.**

The following reactions were obtained on adding 10 volumes of this test liquor to the 5 volumes of oil which had just been acted upon by 1 part of nitric acid:
OILS.

A fibrous mass is formed. | A fluid mass is formed.
---|---
India-nut | white. | Cod-liver. Linseed - lowish.
Castor | red. | Popy (light) | - red.
French nut | light | Neat's foot | yellow.
Hempseed | brown. | French nut | yellow.

Having given in a previous paragraph some of the most useful reactions noted in this table, attention will simply be called to the following mixtures: neat's-foot with rape, Gallipoli with poppy, castor with poppy, hempseed with linseed, sperm with French nut, and Gallipoli with French nut. It is necessary also here to mention that the brown liquor on which the semi-saponified mass of sesame oil swins, is a very delicate and characteristic reaction.

The next test used is phosphoric acid. One part by measure of syrupy trihydrated phosphoric acid is agitated with 5 parts of oil. The only reaction to be noticed is the dark red color, rapidly becoming black, which phosphoric acid imparts exclusively to the fish oils, as it enables us to detect 1 part of these oils in 1,000 parts of any other animal or vegetable oils, and even at this degree of dilution, a distinct coloration is communicated to the mixture.

**Mixture of sulphuric and nitric acid.**

This test is formed of equal volumes of sulphuric acid of sp. gr. 1:845, and nitric acid of sp. gr. 1:330, and is thus used: one volume of this mixture is mixed with 5 volumes of oil, and allowed to stand 2 minutes. By this test 3 of the oils remain nearly colorless, viz., those of poppy, olive, and India-nut, while all the others become brown, except sesame, hempseed, and linseed, which become green, turning after, sesame, intense red, and hempseed and linseed, black.

**Aqua regia.**

This test is composed of 25 volumes of hydrochloric acid of sp. gr. 1:155, and 1 volume of nitric acid of sp. gr. 1:330, and allowed to stand about 5 hours; the reactions in the following table are those which take place when a mixture of 5 volumes of oil and 1 of the aqua regia is agitated and allowed to stand 5 minutes.

<table>
<thead>
<tr>
<th>Not Colored.</th>
<th>Colored.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallipoli.</td>
<td>Seal (slight)</td>
</tr>
<tr>
<td>India-nut.</td>
<td>Cod-liver.</td>
</tr>
<tr>
<td>Pale rapeseed.</td>
<td></td>
</tr>
<tr>
<td>Poppy.</td>
<td></td>
</tr>
<tr>
<td>Castor.</td>
<td></td>
</tr>
</tbody>
</table>

When the facts contained in this table are compared with the preceding ones, we are struck with their uniformity, and are led to infer that no marked action had taken place; but this conclusion is erroneous, as most of them assume a vivid and distinct coloration on the addition of solution of soda of sp. gr. 1:640, as seen in the following table:

<table>
<thead>
<tr>
<th>A fibrous mass is formed.</th>
<th>A fluid mass is formed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallipoli (yellowish).</td>
<td>white.</td>
</tr>
<tr>
<td>India-nut.</td>
<td>pale</td>
</tr>
</tbody>
</table>
| Pale rapeseed (yellowish). | orange | Sell | Poppy | orange with 
| | with | | | liquor. |
| Castor | pale | light | Sesame | beneath. 
| French nut | orange | brown. |
| Hempseed | light | brown. | Linseed | orange. |
| Oil       | Carboxylic Acid | Sulphuric Acid | Sulphuric Acid | Sulphate Acid | Nitric Acid | Nitric Acid | Nitric Acid | + Carboxylic Acid | + Sulphuric Acid | + Sulphate Acid | Phosphoric Acid | Sulphate Acid | Aqua Regia |
|-----------|-----------------|----------------|---------------|---------------|-------------|-------------|-------------|------------------|-----------------|----------------|----------------|---------------|-------------|------------|
| Gallipoli | Slight yellow.  | Ditto           | Ditto          | Ditto          | Ditto        | Ditto        | Ditto        | Ditto             | Ditto            | Ditto            | Ditto           | Ditto         | Ditto       |
| India-um  | Thick and white.| Dirty white.    | Light brown.   | Light brown.   | Ditto        | Ditto        | Ditto        | Ditto             | Ditto            | Ditto            | Ditto           | Ditto         | Ditto       |
| Poppy     | Slight yellow.  | Ditto           | Ditto          | Ditto          | Ditto        | Ditto        | Ditto        | Ditto             | Ditto            | Ditto            | Ditto           | Ditto         | Ditto       |
| Seal      | Ditto           | Ditto          | Ditto          | Ditto          | Ditto        | Ditto        | Ditto        | Ditto             | Ditto            | Ditto            | Ditto           | Ditto         | Ditto       |
| Cod liver | Ditto           | Ditto          | Ditto          | Ditto          | Ditto        | Ditto        | Ditto        | Ditto             | Ditto            | Ditto            | Ditto           | Ditto         | Ditto       |

**General Table of Reactions.**

<table>
<thead>
<tr>
<th>OILS</th>
<th>Castor Soda</th>
<th>Sulphuric Acid</th>
<th>Sulphate Acid</th>
<th>Nitric Acid</th>
<th>+ Carboxylic Acid</th>
<th>+ Sulphuric Acid</th>
<th>+ Sulphate Acid</th>
<th>Phosphoric Acid</th>
<th>Sulphate Acid</th>
<th>Aqua Regia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallipoli</td>
<td>Slight yellow.</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
</tr>
<tr>
<td>India-um</td>
<td>Thick and white.</td>
<td>Dirty white.</td>
<td>Light brown.</td>
<td>Light brown.</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
</tr>
<tr>
<td>Poppy</td>
<td>Slight yellow.</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
</tr>
<tr>
<td>Seal</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
</tr>
<tr>
<td>Cod liver</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
<td>Ditto</td>
</tr>
</tbody>
</table>
The effects described in this table are such that we can discover with facility 10 per cent. of a given oil in many cases of adulteration; for example, poppy in rape, olive in Gallipoli and India-nut, as all of them assume a pale rose color; but when poppy is mixed with olive or castor oils, there is a decrease in the consistency of the semi-saponified matter.

By the aid of the above reagents we can also ascertain the presence of 10 per cent. of French nut in olive or linseed oils, as the semi-saponified mass becomes the more fluid, and the presence of French nut in pale rape, Gallipoli, or India-nut oils, is recognized in consequence of their white mass acquiring an orange hue; linseed oil is detected in hempseed oil, as it renders the fibrous mass of the latter more mucilaginous.

Sesame oil also gives with this reagent the same reaction as with nitric acid and alkali, and poppy oil is distinguished from all other oils, by giving, in this case, a semi-saponified mass of a beautiful rose color.

To give an idea how the above tables are to be used, Mr. Calvert supposes a sample of rapeseed oil adulterated with one very difficult to discover. He first applies the eau-stone test, which, on giving a white mass, proves the absence of the fish oils, together with those of hempseed or linseed; and as no distinct reaction is produced by the sample of oil under examination with the 3 sulphuric and nitric acids above mentioned, poppy and sesame oils are thrown out as they are reddened, near's-foot oil, India-nut, castor, olive, and lard oils resting only in the scale of probability. In order to discover which of these is mixed with the suspected oil, a portion of it is agitated first with nitric acid of sp. gr. 1.300, and then with eau-stone, and their mutual action excludes near's-foot, India-nut, and castor oils as the sample does not give a fluid semi-saponified mass. The absence of olive oil is proved by no green coloration being obtained on the application of syrupsy phosphoric acid. As to the presence of lard oil, it is ascertained on eau-stone soda being added to the oil which has been previously acted on by aqua regia, as the latter gives a fibrous yellowish semi-saponified mass, whilst the former yields a pink fluid one.

In order to facilitate the detection of any adulteration, Mr. Calvert, gives a general table of the preceding reactions. (See table on preceding page.)—H. K. B.

OPAL may be regarded as an un cleavable quartz. Its fracture, conchoidal; lustre, vitreous or resinous; colors, white, yellow, red, brown, green, gray. Lively play of light; hardness, 5 to 6½; specific gravity, 2.091. It occurs in small kidney-shaped and stalactite shapes, and large tubercle concretions. The phenomena of the play of colors in precious opal have not been satisfactorily explained. It seems to be connected with the regular structure of the mineral. Haüy attributes the play of colors to the fissures of the interior being filled with films of air agreeably with the law of Newton's colored rings. Mols, however, thinks this would produce iridescence merely. Brewster concludes that it is owing to fissures and cracks in the interior of the mass of a uniform shape. It is said that the opal which grows after a while dull and opaque may be restored to its former beauty if put for a short time in water or oil.

The precious opal stands high in estimation, and is considered one of the most valuable gems, the size and beauty of the stone and the variety of the colors determining its value. The so-called "mountain of light," an Hungarian opal in the Great Exhibition of 1851, weighed 529½ carats, and was estimated at £4,000 sterling.

In Viaca is a precious opal weighing 17 oz. and it is said a jeweller of Amsterdam offered half a million of florins for it, which was refused.

Hydrophane, or eolius mundi, is a variety of opal without transparency, but acquiring it when immersed in water, or in any transparent fluid. Precious opal was found by Klaproth to consist of silica, 50; water, 10; which is a very curious combination. Hungary has long been the only locality of precious opal, where it occurs near Czehan, along with common and semi-opal, in a kind of porphyry. Fine varieties have, however, been lately discovered in the Faroe islands; and most beautiful ones, sometimes quite transparent, near Naques à Dios, in the province of Honduras, America. The red and yellow bright colored varieties of fire-opal are found near Zimapán, in Mexico. Precious opal, when fashioned for a gem, is generally cut with a convex surface; and if large, pure, and exhibiting a bright play of colors, is of considerable value. In modern times, fine opals of moderate bulk have been frequently sold at the price of diamonds of equal size; the Turks being particularly fond of them. The estimation in which opal was held by the ancients is hardly credible. Nonius, the Roman senator, preferred banishment to parting with his favorite opal, which was coveted by Mark Antony. Opal which appears quite red when held against the light, is called girasol by the French; a name also given to the sapphire or corundum asteria or star-stone.

OPERAMETER. is the name given to an apparatus invented by Samuel Walker, of Leeds. It consists of a train of toothed wheels and pinions enclosed in a box, having indexes attached to the central arbor, like the hands of a clock, and a dial plate; whereby the number of rotations of a shaft projecting from the posterior part of the box is shown. If this shaft be connected by any convenient means to the working parts of a gig mill, shearing frame, or any other machinery of that kind for dressing cloths, the number of rotations made
by the operating machine will be exhibited by the indexes upon the dial plate of this apparatus.

A similar clock-work mechanism, called a counter, has been for a great many years employed in the cotton factories and in the pumping engines of the Cornish and other mines, to indicate the number of revolutions of the main shaft of the mill or of the strokes of the piston. A common pendulum or spring-clock is commonly set up alongside of the counter; and sometimes the indexes of both are regulated to go together.

Opium is the juice which exudes from incisions made in the heads of ripe poppies, 

(Papaver somniferum,) rendered concrete by exposure to the air. The best opium which is found in the European markets comes from Asia Minor and Egypt; what is imported from India is reckoned inferior in quality. This is the most valuable of all the vegetable products of the gum-resin family, and very remarkable for the complexity of its chemical composition.

Orcelle Weeds. The cylindrical and flat species of Roccella used in the manufacture of Orchel and Cobbeir, are so called by the makers.

Dr. Pereira says Mr. Harman Viger, of Bristol, "inform me that every lichen but the best orchelweed is gone, or rapidly going out of use, not from deterioration of their quality, for, being allowed to grow, they are finer than ever; but because the Angola weed is so superior in quality, and so low priced and abundant, that the product of a very few other lichens would pay the expense of manufacture." In the Philosophical Transactions for 1848, Dr. Stenhouse has a valuable paper on the coloring matters of the lichens. From it we extract his directions for estimating the coloring matter in lichens by means of a solution of hypochlorite of lime.

Any convenient quantity of the orchelweed may be cut into very small pieces, and then macerated with milk of lime, till the coloring matter is extracted. Three or four macerations are quite sufficient for this purpose, if the lichen has been sufficiently comminuted. The clear liquors should be filtered and mixed together. A solution of bleaching powder of known strength should then be poured into the lime solution from a graduated alkali-meter. The moment the bleaching liquor comes in contact with the lime solution of the lichen, a blood-red color is produced, which disappears in a minute or two, and the liquid has only a deep yellow color. A new quantity of the bleaching liquid should then be poured into the lime solution, and the mixture carefully stirred. This operation should be repeated so long as the addition of the hypochlorite to the solution of the red color, for this shows that the lime solution still contains unoxidized colorific principle. Towards the end of the process, the bleaching solution should be added by only a few drops at a time, the mixture being carefully stirred between each addition. We have only to note how many measures of the bleaching liquid have been required to destroy the coloring matter in the solution, to determine the amount of the colorific principle it contained.

Dr. Stenhouse suggests the following method for extracting the colorific principle for transport:---Cut the lichens into small pieces, macerate them in wooden vats with milk of lime, and saturate the solution with either muriatic or acetic acid. The gelatinous principle is then to be collected on cloths and dried by a gentle heat. In this way the whole of the heat can be easily extracted, and the dried extract transported from the most distant localities.

Ores, Dressing of. In metallic veins the deposits of ore are extremely irregular and much intermixed with gangue or vein stone. In excavating the lode, it is usual for the miner to effect a partial separation of the valuable from the worthless portion; the former he temporarily stows away in some open place underground, whilst the latter is either employed to fill up useless excavations, or in due course sent to surface to be lodged on the waste heaps. From time to time the valuable part of the lode is drawn to the top of the shaft, and from thence conveyed to the dressing floors, where it has to be prepared for metallurgical treatment.

This process is known as dressing, and in the majority of instances includes a series of operations. In this country it is chiefly restricted to mechanical treatment, the chemical manipulation being performed by the smelter. Hand labor, picking, washing, sizing, and reducing machinery, together with water-concentrating apparatus, comprise the usual resources of the dresser, but sometimes he may find it useful to have recourse to the furnace, since it may happen that by slightly changing the chemical state of the substances that compose the ore, the earthy parts may become more easily separable, as also the other foreign matters. With this view, the ores of tin are often calcined, which, by separating the arsenic and oxidizing the iron and copper, furnishes the means of obtaining, by the subsequent washing, an oxide of tin much purer than could be otherwise procured. In general, however, these are rare cases; so that the washing almost always immediately succeeds the picking, crushing, or stamping processes.

Before entering upon the description of machinery employed in the concentration of ores, it is important to notice the principles upon which the various mechanical operations are based.
ORES, DRESSING OF.

If bodies of various sizes, forms, and densities be allowed to fall into a liquid, in a state of rest, the amount of resistance which they experience will be very unequal, and consequently they will not arrive at the bottom at the same time. This necessarily produces a sort of classification of the fragments, which becomes apparent on examining the order in which they have been deposited.

If it be supposed that the substances have similar forms and dimensions, and differ from each other in density only, and it is known that the resistance which a body will experience in moving through a liquid medium depends solely on its form and extent of surfaces, and not on its specific gravity, it follows that all substances will lose under similar circumstances an equal amount of moving force.

This loss is proportionally greater on light bodies than in those having more considerable density. The former for this reason fall through the liquid with less rapidity than the denser fragments, and must therefore arrive later at the bottom, so that the deposit will be constituted of different strata, arranged in direct relation to their various densities, the heaviest being at the bottom, and the lightest at the top of the series.

Supposing, on the contrary, that all the bodies which fall through the water possess similar forms and equal specific gravities, and that they only differ from each other in point of volume, it is evident that the rapidity of motion will be in proportion to their sizes, and the larger fragments will be deposited at the bottom of the vessel.

As the bodies on starting are supposed to have the same forms and densities, it follows that the resistance they experience whilst descending through water will be in proportion to the surface exposed, and as the volumes of bodies very according to the cubes of their corresponding dimensions, whilst the surfaces only vary in accordance with the squares of the same measurements, it will be seen that the force of movement animating them is regulated by their cubes whilst their resistance is in proportion to their squares.

If, lastly, it be imagined that all the fragments have the same volume and density but are of various forms, it follows that those possessing the largest amount of surface will arrive at the bottom last, and consequently the upper part of the deposit will consist of the thinnest pieces.

It is evidently then of the greatest importance that the grains of ore which are to be concentrated by washing should be as nearly as possible of the same size, or otherwise the smaller surface of one fragment, in proportion to its weight, will in a measure compensate for the greater density of another, and thus cause it to assume a position in the series to which by its constitution it is not entitled.

This difficulty is constantly found to occur in practice, and, in order as much as possible to obviate it, care is taken to separate by the use of sieves and trommels into distinct parcels, the fragments which have respectively nearly the same size. Although by this means the grains of ore may to a certain extent be classified according to their regular dimensions, it is impossible by any mechanical contrivance to regulate their forms, which must greatly depend on the natural cleavages of the substances operated on, and hence this circumstance must always in some degree affect the results obtained.

Each of the broken fragments of ore must necessarily belong to one of the three following classes:—the first class consists of those which are composed of the mineral sought without admixture of earthy matter. The second will comprehend the fragments which are made up of a mixture of mineral ore and earthy substances, whilst the third division may be wholly composed of earthy gangue without the presence of metallic ore. By a successful washing these three classes should be separated from each other.

The most difficult and expensive vein stuff for the dressing floors is that in which the constituents have nearly an uniform aggregation, and where the specific gravity of the several substances approximate closely to each other. In such case the ore is only separated from the waste after much care and labor, and often at the loss of a considerable portion of the ore itself. When, however, the ore is massive and distinct from the gangue, and the specific gravity of the latter much less than the former, then the operation of cleaning is usually very simple, effected cheaply, and with but little loss on the ore originally present.

The losses which may be sustained in the manipulation and enrichment of ores is a matter of great importance, and demands not only direct attention from the chief agent, but also calls for the constant vigilance of the dresser. No one can approve of a system which admits to record the initial quantity of ore brought to the surface, noting only the tonnage and percentage of the parcel produced for sampling.

Yet such inattention prevails generally in the mining districts of this country. What would be thought of a smelter who might systematically purchase and receive ores without ascertaining their produce, and reduce them in furnaces totally unfitted for the purpose, without regarding the losses which might be sustained? If he became insolvent it would excite no surprise, but, on the contrary, the public would most likely look upon his position as the inevitable result of a defective and reprehensible mode of working.

It will be admitted that mineral exploitations are of a highly hazardous nature, and
ORES, DRESSING OF.

that the risk of profit ought not to be increased either by ignorance or carelessness. When ores are discovered, usually after the expenditure of much money, a certain amount of productive and deal cost is incurred before they can be rendered at the dressing floors; if then the least waste takes place there is not only a loss per se, but the mine expenditure is augmented upon the lessened quantity, hence in no department of mining economics is it more essential to secure higher practical talent than in the dressing and management of vein stuff. The individual entrusted with this duty should be competent to assay the ores, have a knowledge of the losses resulting from their metallurgic treatment, and know approximately the cost of enriching them on the floors as well as of smelting them; he will then conduct his operations so that the cost and loss in dressing will be less than the cost and loss in smelting.

Some of the more friable ores, when simply exposed to the influence of water, exhibit a large mechanical loss, so much so, that it is considered oftentimes more profitable to put them to pile without attempting their enrichment. Now it may be laid down as an axiom that water will always steal ore, and the longer it is exposed to its influence, and the more complicated the manipulation, the greater will be the loss incurred. In addition, the constitution of certain ores is so peculiar and delicate, that any attempt to concentrate them beyond a given standard, by varying the treatment, is seen to lead to an enormous loss, as will be apparent by inspecting the following memoranda of practical results:

(A.)—The ore operated upon was sulphide of lead, associated with finely disseminated iron pyrites, oxide of iron, quartz, and a small portion of clay slate. In each case the vein stuff assayed 17 per cent. of metal.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>by weight</td>
<td>by weight</td>
</tr>
<tr>
<td>1 washed and concentrated</td>
<td>61 per cent.</td>
</tr>
<tr>
<td>1 lost by roasting</td>
<td>39 &quot;</td>
</tr>
<tr>
<td>24 washed and do.</td>
<td>The loss on metal</td>
</tr>
<tr>
<td>1.56 washed and concentrated</td>
<td>originally present</td>
</tr>
<tr>
<td>8 roasted, washed, do.</td>
<td>43 &quot;</td>
</tr>
<tr>
<td>8 &quot;</td>
<td>50 &quot;</td>
</tr>
<tr>
<td>1.56 &quot;</td>
<td>33 &quot;</td>
</tr>
<tr>
<td>8 &quot;</td>
<td>16 2/3 &quot;</td>
</tr>
</tbody>
</table>

(B.)—Took two parcels of argentiferous lead ore, associated with carbonate of iron, a little quartz, and blende. Weight 34½ tons, which assayed 421 per cent. for lead, and 29 oz. of silver per ton of metal. Crushed and carefully elaborated the same through jiggig and battle apparatus, obtained 14½ tons of ore, giving 84 per cent. for lead, and 22 ounces of silver per ton of metal. The produce for lead was therefore raised 12 units at a loss of 49 per cent. of the initial quantity of metal and 95 ounces of silver. The commercial loss attending this operation, after making the several charges and allowances incident to the metallurgy treatment, was £911 14s., or equal to £214 1s. per ton on the original weight.

Additional instances of heavy losses incurred in the concentrating process could be adduced if space permitted; but it may not be unwise to direct special attention to the great waste often connected with the manipulation of both tin and argentiferous ores. In the former it occurs chiefly from the oxide of tin being much diffused through hard vein stone, requiring severe mechanical treatment in order to liberate it, whilst in the latter the silver (not unfrequently combined mechanically), imperceptible to the eye, floating away when subjected to water, and so subtle as to evade the most delicately devised apparatus. The loss accruing in one large undertaking from this source alone upon 1,100 tons of ore was 3,026 ounces of silver worth £380, or equal to the interest on £16,000, at the rate of 5 per cent. per annum.

In order to determine the loss of metal which may arise in enriching ores, accurate assays and notations should be made of the quantity of vein stuff lodged on the floors, which should be compared with the metallic contents rendered merchantable, and the differences estimated.

It is not possible to ascertain the value of an improvement which would secure an additional one per cent. from the quantity of orey stuff annually sent to surface from the several mines in the United Kingdom; but if it be reckoned only upon the sale value it would be scarcely less than £40,000 per annum.

In determining the site for a dressing floor, and in making the mechanical arrangements, various points suggest themselves; since, if they were overlooked, much loss would ensue to the undertaking, or otherwise it is evident that they could only be corrected by involving the proprietary in an increased outlay as well as a greater current expenditure. The first consideration should be to secure an ample supply of water, with a good fall, and an extensive area of ground. With advantages of this nature the machinery will be worked cheaply, the stuff gravitate through the various processes without returning to create double
curriage expenses, whilst the castaways may be sent to the waste heaps at a minimum cost. The second point to be settled, is the class of machinery to be employed. This must obviously be based upon the character which the ores may present. If massive, and associated with light waste, simple apparatus will suffice; but if the ore be sparsely diffused among heavy vein stone, it is probable that the various apparatus will have to be constructed with great nicety, varied in their principles of action, and that much precaution will have to be observed in order to create as little slime as possible, as well as to secure the initial quantity of ore against undue loss. In the disposition of the machinery there is also considerable scope for practical intelligence; it is not enough to wash, crush, jig, and boulde the ores, mixing the resulting smulls incongruously together; but a judicious sorting should be commenced at the wash kilns, and upon this basis the various sizes kept distinct whilst passing through the washing floors. The dresser should also take care to keep the several ranges of mineral produce and degrees of fineness together.

The following general deductions will be found serviceable:

First.—Absolute perfection in separation according to specific gravity cannot be arrived at, chiefly on account of the irregularity of form of the various grains to be operated upon.

Second.—The more finely divided the stuff to be treated, the greater is the amount of labor and care required, and the more imperfect will be the separation.

Third.—That reducing machine may be considered the most perfect which produces the least quantity of stuff finer than that which it is intended to produce.

Fourth.—In determining the degree of fineness to which a mineral should be reduced, to consider the metallurgical value of the ore contained in it, and to set against this the value of the loss which will probably be incurred, together with the labor and expense attendant upon the manipulation.

Fifth.—The vein stuff should be reduced to such a degree of fineness that the largest proportion of deals and clean ore should be obtained by the first operation, thus saving the labor and preventing the loss incident to a finer subdivision of the ore and more extended treatment.

Sixth.—That apparatus or plan of dressing may be considered the most efficient which with stuff of a given size allows at an equal cost of the most perfect separation, and of the proper separation of stuff of nearly equal specific gravity.

The average percentage to which the crop is to be brought, and the highest percentage to be allowed in the castaways being determined, it is evident that the more perfect the degree of separation the greater will be the amount of crop and castaways obtained at each operation, and the quantity of middles or stuff to be re-worked will be diminished.

Seventh.—We may further consider as a great improvement in dressing operations such apparatus or plan of working as will allow, without a disproportionate increase in the cost, of the equally perfect separation of fine stuff as that of the coarser, as now practiced. This will be of especial benefit in the case of finely disseminated ore, which is necessarily obliged to be reduced to a great degree of fineness.

WASHING AND SEPARATING ORES.

The vein stuff, on arriving at the surface, is not only associated with a large amount of gangue, but is frequently much intermixed with clay, rock, and silicious matter.

In order to get rid of the latter substances, it is usually washed and picked. The washing apparatus ought to be so contrived as to allow the cleansing to be effected both cheaply and expeditiously, and for this purpose a good volume of water is always desirable. If a heavier fall can be obtained, it will also be found advantageous. In accordance with the character of the ore the apparatus will have to be varied; but for lead, certain varieties of copper ore, as well as iron, or other abundant ores, the kiln is well adapted. In many mines rectangular grates are fitted to the bottom of the kilns, but a perforated plate would be found to furnish better results, since the former allows of the passage of flat irregular masses of stone, rendering the treatment in the jiggling sleeves less successful. The holes in the perforated plate should be conical, the largest diameter underneath, so that the stones may have unobstructed passage. In connection with the kiln-plate a sizing trommel should be used, and in order to economize both time and expenditure it would be judicious to introduce the vein stuff, and discharge the castaways by means of railways.

The picking of the stuff is a highly important operation. As a rule all picked ore should be selected, and the drudge deprived of the largest possible amount of waste before it is sent to the crusher. It is highly fallacious to suppose, because machinery will deal with large quantities expeditiously, that it is cheaper to subject the mass to its action; on the contrary, if correct calculations are made of the losses which will ensue on the initial quantity of ore before the residue is ready for the pile, the cost of the several intricate manipulations requisite to get rid of the castaways, the wear, tear, and maintenance of machinery, it will appear in the majority of cases that the most profitable method is to incur an extra first charge in order to reject the sterile portions by means of hand labor. The ragging hammer should therefore be brought into free requisition, and all worthless stones at once rejected; then in spalling such portions as have been ragged an additional
ORES, DRESSING OF.

quantity of refuse should be excluded, whilst in the process of cobbing either ragged or spalled work, the greatest care and attention should be given in order to bring the dradge to a maximum degree of richness.

Among the washings and washings which ores are made to undergo, we would notice those practised on the Continent, grilles anglaises, and step-washings of Hungary, laveuses à gradins. These methods of freeing the ores from pulverulent matters, consist in placing them, at their out-put from the mine, upon gratings, and bringing over them a stream of water, which merely takes down through the bars the small fragments, but carries off the finer portions. The latter are received in cisterns, where they are allowed to rest long enough to settle to the bottom. The washing by steps is an extension of the preceding plan. To form an idea of this, let us imagine a series of gratings placed successively at different levels, so that the water, arriving on the highest, where the ore for washing lies, carries off a portion of it, through this first grate upon a second closer in its bars, thence to a third, &c., and finally into labyrinths or cisterns of deposition.

The grilles anglaises are similar to the steping tables used at Idria. The system of these gradins is represented in fig. 469. There are 8 such systems in the works at Idria for sorting the small fragments of quicksilver ore intended for the stamping mill. These fragments are but moderately rich in metal, and are picked up at random, of various sizes, from that of the fist to a grain of dust.

The ores are placed in the chest a, below the level of which 7 gratings are distributed, so that the fragments which pass through the first, b, proceed by an inclined conduit on to the second grate, c, and so in succession. (See the conduits I, a, p.) In front, and on a level with each of the gratings b, c, d, &c., a child is stationed on one of the floors, 1, 2, 3, to 7.

A current of water, which falls into the chest a, carries the fragments of ore upon the gratings. The pieces which remain upon the two gratings b and c, are thrown on the adjoining table e, where they undergo a sorting by hand; there the pieces are classified, 1, into gangue to be thrown away; 2, into ore for stamping-mill; 3, into ore to be sent directly to the furnace. The pieces which remain on each of the succeeding gratings, d, e, f, g, h, are deposited on those of the floors, 5 to 7, in front of each. Before every one of these shelves a deposit-sieve is established, (see t, u,) and the workmen in charge of it stand in one of the corresponding boxes, marked 8 to 12. The sieve is represented only in front of the chest h, for the sake of clearness.
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Each of the workmen placed in 8, 9, 10, 11, 12, operates on the heap before him; the upper layer of the deposit formed in his sieve is sent to the stamping-house, and the inferior layer directly to the furnace.

As to the grains which, after traversing the five grates, have arrived at the chest, they are washed in the two chests $y$, which are analogous to the German chests. The upper layer of what is deposited in $y$ is sent to the furnace; the rest is treated anew.

The kiln before adverted to is explained by fig. 470.

The vein stuff is brought from the shaft by means of tram wagons, into the hopper $x$; water flows from the launder $u$, one portion distributing itself at the foot of the hopper, the other upon a cast-iron plate perforated with holes $1\frac{4}{10}$ inch diameter at top, $1\frac{1}{2}$ inch diameter at bottom, and 2 inches distant from centre to centre; the plate being 4 feet by 3 feet 6 inches. Between $c$ and $e$, the washer stands. The fine stuff it takes through the plate-holes, and that which is too coarse is drawn to $e$. Children standing on $u$, select the prill and dradge from the pile $v$, discharging such stones as are valueless through the shoot $r$, into the wagon beneath. The trommel $n$ is constructed of perforated plates, having different degrees of fineness, in order to size the stuff which passes through into bins or compartments.

Ragging.—It has been remarked that, in breaking the lode underground, numerous rocks are produced throughout which valuable ore is more or less disseminated. After these stones are washed they are ragged. This operation consists simply in reducing the stones to a smaller size, and rejecting as many of the sterile stones as can be readily picked out. The reduced heap is ultimately taken to the spallers and cobbers. The weight of a steel-headed ragging hammer varies from six to eight pounds.

Spalling, fig. 472, is usually performed by women. The object is to break the stones

to a proper size for the bucking-hammer or crushing-mill, and at the same time to cast aside such lumps as are destitute of ore. The hammer employed is made of cast steel, and is set upon a light plant handle. Its weight is about sixteen ounces, and its cost eightpence. A practised spaller will produce about one ton of stuff per day, but the quantity must necessarily depend upon the hardness and nature of the stone.

Cobbing, fig. 473.—This work is also generally performed by women or young girls. It consists of picking the best work from the drudge, and with a peculiarly shaped hammer detaching from each piece the inferior portions, and thus forming either prill or best dradge ore. An expert cobber will manage to pass through her hands about ten hundred weights of tolerably hard stuff per ten hours.

Sizing Apparatus.—In the varied processes of dressing, no point is of greater importance than that of correctly sizing the vein stuff, neither is there one demanding the exercise of a more correct judgment. If the particles of ore be reduced below their natural size, a source of loss is immediately created, whilst, if they are not brought within the limit of their size, a portion of waste will probably adhere to each atom, forming a serious difference in the aggregate quantity of castaways, although such waste may afford but a low average percentage. The holes in the sieves or trommels should therefore be proportioned to the nature of the ore, but such apparatus should also be introduced wherever necessary. To the crushing-mill, trommels are essential, whilst it will be found highly advantageous to employ them for the purpose of dividing the stuff wherever it may become intermixed. The simplest form of sizing is perhaps by the hand riddle, fig. 474, which is formed of a circular hoop of oak, $\frac{3}{4}$ of an inch thick and six inches deep. Its diameter ranges from eighteen to twenty inches,
ORES, DRESSING OF.

The bottom is made of a meshwork of copper or iron wire. The weight of an iron wire riddle is about seven pounds, and its cost 4s. 6d.

Fig. 475 represents a swing sieve employed in the mines on the Continent. a, box into which the stuff to be sifted is introduced; b, regulating door; c, pendulating rod attaching the sieve frame to the frame e; f, friction roller carrying the sieve frame g. At h springs are fitted to each side of the frame, in order to give it a vibratory action, i, rod, giving motion to the apparatus. The width of the sieve frame is about one-third its length, but the sieve bottom only extends from the box a two-thirds of the length. The bottom of the sieve frame is subsequently contracted so as to form a shoot. At the extensive mines of Comorn, near Duren, these sizing frames are largely employed in connection with stamping-mills.

The circular hand-riddle has only recently been introduced into the mines of Cornwall. Although this is in advance of hand riddling, yet it is by no means equal to the large sizing trommels employed in Germany.

The ore is thrown in at a, fig. 476, the coarser pieces passing longitudinally through the riddle into the shoot n. The riddle is turned by a hook handle, as shown in the illustration; the meshes of the sieve vary from ½ of an inch to one inch square, according to the character and quality of the vein stuff to be operated upon.

Figs. 477, 478 show an elevation and ground plan of a series of flat separating sieves. A A', B B' is a strong wooden frame; M M, guides for frame; N N, basement upon which the sieve frame rests; P, cistern fitted with perforated plate through which clean water is distributed upon the sieves; T, hopper supplying the stuff to be sifted; S S bottom of ditto. The sieves are lifted by the rod l, and make from 40 to 50 beats per minute. The sieves are set about eight inches apart, and discharge the stuff upon the inclines p p p.

The holes in No. 1 sieve are ¼ inch diameter.

<table>
<thead>
<tr>
<th>Size</th>
<th>Number</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>⅛</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>⅛½</td>
</tr>
<tr>
<td>3½</td>
<td>4½</td>
<td>⅛/12</td>
</tr>
</tbody>
</table>

The apparatus is employed in the Clausthal Valley.

Fig. 479 represents the trommel or sizing sieves in operation at the Devon Great Consols. Although the yield of ore at these mines is extremely large, it may not be generally known that much of it is obtained from stuff yielding no more than from ½ to 1½ per cent. of metal. The product of the lode on arriving at the surface is cobbled and divided into two classes, the first going to market without further elaboration, whilst the drudge or inferior portion is treated by various processes of washing. The whole is however crushed to such a degree of fineness as to pass through the following holes:—
ORES, DRESSING OF.

Trommel A, holes \(\frac{3}{16}\) inch diameter.

- B, \(\frac{7}{12}\) "
- C, \(\frac{7}{10}\) "
- D, \(\frac{1}{4}\) "

The trommels are each 6 feet long, 24 inches diameter at the large end, and 18 inches diameter at the smaller, making 20 revolutions per minute, and altogether affording an area of 6,000 square inches.
ORES, DRESSING OF.

Crushing Machinery.

Various crushing machines are described under Grinding and Crushing Machinery; but it may be observed that this section of the dressing department deserves careful attention, as the results are more or less affected according to the mode of working and adjusting this class of machinery. The crusher is, as it were, the starting or radiating point for treating the drudge work, and if considerable care is not exercised here, not only will there be much loss of power, but also of the initial quantity of ore. In the mining districts of this country it is usual to introduce rough and fine drudge together; no preliminary division of the stuff is attempted; the hopper is continuously charged, and that portion which is not reduced sufficiently fine is returned by the raff-wheel to be recrushed.

The consequence is, the motion is uneven, strains are inflicted on the machinery, and more time as well as power is necessary for the purpose of realizing a given result. Valuable improvements could be effected by first mechanically sorting or dividing the drudge, expediting the speed of the rolls, fitting them with steel faces, setting them so as not to reduce the grain of ore below its normal size, giving them a uniform supply by means of a tilting shoot, and instead of returning the raff to the rolls conveying it to a second series of smaller dimensions, adjusted and managed in a similar way. To each set of rolls there should be fitted sifting trommels, with holes proportioned to the character of the ore, whilst in many instances it would be found judicious to discharge a stream of water on the rolls with a view of expediting the crushing.

In small mines, bucking, fig. 480, is resorted to instead of employing the crushing-mill.

This operation consists of pounding pieces of mixed ore on a slab of iron A, by means of a hammer or bucket B. The wall on which the plate A is placed, is about 3 feet high. The stuff to be pounded is placed behind the slab, and is drawn upon and swept off the plate by the left hand. In Cornwall it is customary to keep time with the blows and to stand to the bench, but in Derbyshire each operator works independently, and is usually seated.

The bucket, fig. 481, is formed of a wrought-iron steel-faced plate A, 3 inches square, with a socket B, for receiving a wooden handle C. Its cost is about 1s. 4d.

Stamps.

Tin and some other of the more valuable ores are usually associated with and minutely disseminated in a hard crystalline gangue, requiring to be reduced to a fine powder before the valuable portions can be extracted.

Various contrivances have been employed for this purpose, but none of them seem to have entered into competition with the stamping-mill. This apparatus essentially consists of a number of cast-iron pestles, each measuring about 20 inches high, and 6 by 10 inches in the section. These are secured either to a wrought-iron or wooden lifter; a projecting arm is placed towards the top on each lifter, which may be shidden up and down so as to meet the wear of the pestle or any other irregularity. These lifters are retained in their vertical position by suitable metal or wooden supports. Motion is communicated by a revolving shaft in front, fitted with four or five projecting cams, each of which catches the arm, and lifting the pestle from 8 to 10 inches, lets it suddenly fall on the substances which may be underneath. The bottom on which the heads fall is formed by introducing hard stones or other suitable material, and pounding it until it becomes sufficiently solid. In most parts of the Continent of Europe, on the contrary, stamping-mills are provided with solid cast-iron bottoms; these are, however, subject to the inconvenience of requiring frequent renewal.

Around the pestles a wooden box or cofer is constructed, and covered in at the top; the back is partly open at the bottom in order to admit the vein stuff. On each side one, and in front two openings are made, 7 or 8 inches square, which are fitted with wrought-iron
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For the reception of perforated iron, copper, or brass plates, the bar of the punch or drill being towards the inside. As a precaution against the speedy destruction of the cofer from the constant scattering of fragments of stone, the inside is partially lined with sheet-iron. The stuff to be stamped is supplied on an inclined plane, connected with a hopper at the back, in the front of which is a launder for affording a stream of water to the cofer. The stamped stuff passes through the grates into launders, and is thus directed to the floors. When water is the motive power, the number of heads is limited by the volume and fall of water available; three heads are the least number used, but a larger number is generally preferred. When steam-power is employed, a battery of heads sometimes includes 100 or more pestles. When in action, these are elevated from 40 to 80 times per minute, according to the character of the stuff to be reduced. The pulverization is said to be greatly facilitated by having four heads in the same chest or cofer, about 21 inches apart. Each head is lifted separately, and the cans by which this is done are so disposed on the axle as to make the blows in regular succession. Great care is also taken whether it be in a large or small battery, to prevent any two pestles falling at the same instant; the object being to secure an equal strain against the power. Practical dressers are not well decided as to the order in which the lifting of four heads in one cofer should take place, whether one of the inner pestles should precede the other, or whether a side pestle should be first lifted. A preference, however, seems to be given to the following method:—supposing a spectator to stand in front of a 4-head stamps, left side pestle first, right side second, right middle third, left middle last.

*Fig. 482* represents the elevation of a steam stamps employed in Cornwall. A, axle;

b, cams for lifting heads; c, tongue or projection on lifter; d, n, guides for retaining lifter; e, the lifter; f, head or pestle; g, chest or cofer; h, hopper; J, pass connecting cofer and hopper; k, launder discharging water into the cofer; l, stamps grate; m, launder receiving the stuff which has been flushed through the grates; n, the bottom or bed of stamps.

The stamping process is not so simple as it may appear at first sight. Many of its particulars, such as the form of the cofer, mode of exit for the stuff, weight and rapidity of the pestles, and quantity of water employed, must be varied to suit the mode of dissemination and the structure and character of the ore, as well as of the matrix. Fineness of reduction is by no means always a desideratum, for if some kinds of stuff be reduced too low, much of the ore contained in it will be wasted, hence considerable judgment is necessary in selecting the grate best adapted to the stuff to be operated upon. Sometimes the grate is replaced by the "flesh," which consists of a small hopper-shaped box, fitted to the front of the grate-hole. This box is provided with a shutter, which is raised or lowered according as the ore is required in a fine or rough state. In dry stamping the fineness of the powder depends not on the grate, but on the weight of the pestles, the height of their fall, and the period of their action upon the substances beneath them. The following practical results are derived from the steam stamps at Polperro Tin Mines, Cornwall:

Cylinder of engine, 36 inches diameter.
Diameter of the fly-wheels, 30 feet.
Weight of ditto, with cranks, shaft, and bolts, 424 tons.
Power employed, 55 horses.
Reduced in 12 months, 30,301 tons of vein stuff.
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Average number of revolutions of stamps axles per minute, 81.
Number of heads lifted per minute, 72, each 9 inches high.
Weight of each head, 600 lbs.
Average number of blows performed by each head, 45.
Weight of heads collectively, 10½ tons.
Number of grates, 72.
Exposed area of front grates, 9 x 6 = 54 inches.
Ditto of end grates, 8 x 6 = 48 inches.
Number of holes to the square inch, 140.
Cost of stamping, including maintenance of engine and wear and tear of machinery, 1s. 3½d. per ton of stuff.

JIGGING MACHINERY.

In the jiggie sieve only the initial velocity of the substances to be separated is obtained at each stroke. Were, however, the sieve plunged to a depth of say 20 or 30 feet, the various grains would settle themselves according to their various velocities of fall, one over the other, assuming them to be of a uniform size.

The following table, furnished by Mr. Upfield Green, shows the fall of various spheres in water in one second, the depth being in Prussian inches:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8&quot;</td>
<td>100'</td>
<td>60'923</td>
<td>40'825</td>
<td>29'814</td>
</tr>
<tr>
<td>5-057</td>
<td>84'090</td>
<td>50'532</td>
<td>34'329</td>
<td>25'071</td>
</tr>
<tr>
<td>4&quot;</td>
<td>70'711</td>
<td>42'492</td>
<td>28'868</td>
<td>21'082</td>
</tr>
<tr>
<td>2-928</td>
<td>59'460</td>
<td>35'731</td>
<td>24'255</td>
<td>17'728</td>
</tr>
<tr>
<td>2&quot;</td>
<td>50'</td>
<td>30'046</td>
<td>20'412</td>
<td>14'907</td>
</tr>
<tr>
<td>1-414</td>
<td>42'045</td>
<td>23'266</td>
<td>17'165</td>
<td>12'535</td>
</tr>
<tr>
<td>1&quot;</td>
<td>33'953</td>
<td>21'246</td>
<td>14'434</td>
<td>10'541</td>
</tr>
<tr>
<td>0-700</td>
<td>29'730</td>
<td>17'866</td>
<td>12'187</td>
<td>8'864</td>
</tr>
<tr>
<td>0'5</td>
<td>25&quot;</td>
<td>15'923</td>
<td>10'206</td>
<td>7'454</td>
</tr>
<tr>
<td>0'354</td>
<td>21'022</td>
<td>12'633</td>
<td>8'582</td>
<td>6'268</td>
</tr>
<tr>
<td>0'25</td>
<td>17'678</td>
<td>10'623</td>
<td>7'217</td>
<td>5'270</td>
</tr>
</tbody>
</table>

Now, instead of assuming the substances to be of a uniform size, let it be supposed that they vary; the foregoing table will show that gold of 8 lines would settle at bottom, and that when gold of 2½ lines began to settle, the galena of 8 lines would fall also. With galena of 3½ lines, blende of 8 lines would be associated, and so on.

If, secondly, it be assumed that the substances varied between 4 and 8 lines, some time would elapse, after gold of 4 lines had settled, before the galena would begin to deposit itself. With blende, however, of 4 lines, and quartz of 8, the latter would almost appear at the bottom at this time.

The proportion between the maximum and minimum sizes of the stuff to be operated on should be as the specific gravity of one to the other. Thus,

Gold and galena - - - - - 7½ : 19½ :: 1 = 2.56
Galena and blende - - - - - 4½ : 7½ :: 1 = 1.075
Blende and quartz - - - - - 2½ : 4½ :: 1 = 1.537

Hand Sieve.—This apparatus, fig. 483, is formed of a circular hoop of oak, ²⁄₄ of an inch thick and 6 inches deep. Its diameter ranges from 18 to 20 inches. The bottom is made of copper or iron wire meshes, of various sizes. Sometimes perforated copper plate is employed, when the sieve is termed a copper bottom. The sieve is shaken with the two hands in a cistern or tub of water; an ore vat is however sometimes employed, and either fixed horizontally or in an inclined position. In using this sieve the workman shakes it in the vat with much rapidity and a dexterous toss till he has separated the totally sterile portions from the mingled as well as from the pure ore. He then removes these several quantities with a sheet-iron scraper, called a thiap, and finds beneath them a certain portion of enriched ore.

Dusting Sieve.—This sieve, A, fig. 484, is either constructed with a hair or canvas bot-
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tom; the former is more expensive, but more durable. Its peculiar application is chiefly for the final treatment of ores previous to being put to pile, such ores having first passed through the finest jiggling sieves, yet still maintaining a certain degree of coarseness, and bearing a high specific gravity.

In the separation of ores from light waste, or such minerals as approach one another somewhat closely in their densities, this form of sieve is both good and effective, but to use it properly a considerable amount of dexterity and practice is requisite.

There are two principal methods of using it; by one a motion is given, whereby the waste is being constantly projected and carried over the rim into the sieve by a current of water forced through its bottom. This mode of treatment is adapted for poor ores. In the second case, when the ore is nearly pure but still associated with a heavy gangue, a motion is given to the sieve whereby the water is forced through the ore, and made to traverse the surface of the mineral in concentric circles. This motion collects the waste into the middle of the clean result. By the first method about six tons per day may be passed through by each workman and curch for the second operation. The weight of the sieve varies from four to five pounds, its diameter is twenty-six inches, depth four inches, and cost from 2s. 6d. to 2s. 6d.

A jiggling sieve, constructed as shown in fig. 485, is sometimes employed on the Continent. A represents the table on which the mineral is placed; n is a large kieve of water, in which the sieve is suspended by the iron rod n, set in motion by means of the arrangement, p, q, n, suspended at i, and having at the extremity a box for the reception of small stones, to be used for the purpose of counterpoising the weight of the sieve and several fittings. By moving the rod p, sliding in k, the workman gives the required motion to the sieve, and when its contents have been sufficiently washed he removes them by the same means as when the hand sieve is employed.

Hand Jiggling or Brake Sieve.—The brake sieve, fig. 486, is rectangular, as well as the

cistern in which it is agitated. A, wooden lever, having its axis at f; n, piece of wrought-iron bolted to end of lever a, whilst its upper end passes freely through a slot opening in lever n, and having two shoulder projections c; k, axis of lever n; g, bars connected with lever n, supported on axle k, and from which the iron rods h h depend; j, rectangular sieve; k, under hutch; l, shoot for overflow of water; m, receptacle for retaining any fine,
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ore which may escape with the water from \( \alpha \), as well as for receiving the hutchwork. A boy placed near the end of lever \( \alpha \), by the action of leaping, jerks it smartly up and down, so as to shake effectually the sieve \( \beta \). Each jolt not only makes the fine part pass through the meshes, but changes the relative position of those which remain in the sieve, bringing the purer and heavier pieces eventually to the bottom. The mingled fragments of ore and stony substances lie above them, while the poor and light pieces are at the top; those are first scraped off by the \( \text{limp} \), then the mixed portion, and lastly the ore, which is usually carried to the ore heap. The sieve frame may be made 2 \times 4 feet inside and 8 to 9 inches deep. The hutch should then be 5 feet long, 3 \( \frac{1}{4} \) feet wide, and 4 \( \frac{1}{2} \) feet deep, constructed of good deal boards 2 inches thick. The quantity of stuff which a boy can jig in ten hours will depend upon several circumstances. With a sieve six holes to the square inch and a tolerably light waste, from five to six tons can be operated on.

Machine Jigging.—The machine jigger represented in fig. 487 is constructed on the same principle as the hand apparatus. The hutches are, however, somewhat larger, being six feet long, four feet wide, and four feet deep. \( \alpha \), fly-wheel; \( n \), driving-wheel; \( c \), cog-wheel receiving motion from \( n \), and giving motion to a crank from which depends a rod attached to lever \( \beta \). \( m \) and \( r \), the vertical rods, passes through a slot opening in the wooden lever \( \beta \), and by these several combinations a vertical movement and jerk is given to the sieve contained in the cistern \( g \).

When it is required to discharge the sieve, the lever \( n \) is depressed, and the pin, not seen in the end of lever \( \beta \), traverses in the slot shown in the bridle rod immediately below the bracket. The sieve measures 4 \( \times \) 2 feet and 9 inches deep. It is strengthened by iron bands and numerous slips across the bottom.

A jigger apparatus, fig. 488, has been arranged by Mr. Edward Borlase, of St. Just, Cornwall, and introduced by him at Allenheads, with satisfactory results. At these mines it has been worked in conjunction with the machine, fig. 498, and described at page 657. The larger and denser portion of stuff separated by this apparatus is conveyed by suitable launders to a series of sieves, arranged on the top of a conical reservoir, furnished with a feed pipe for the admission of water, and with an outlet pipe at the bottom. This reservoir is placed within another reservoir, also in the form of an inverted cone, and provided with an outlet pipe at the lower part. \( \alpha \), eccentric giving motion to the sieve; \( n \), hamster conveying stuff to such sieves; \( q \), distributor, either stationary or revolving, as may be required, delivering stuff to the sieves arranged on the top of the conical reservoir; \( r \), valve for discharging the finer portion of the ore; \( g \), internal cistern furnished with an outlet valve \( h \).

The sieves have a slight outward inclination, and the refuse substances with the waste water are carried over and deposited in the conical cistern, \( g \).

The sieves should make from 150 to 290 pulsations per minute, according to the quantity and character of the stuff under treatment.

The following is the result of trials made on 160 tons of stuff, one-half being delivered to Borlase's machine, the other to the common jigger hutch:

<table>
<thead>
<tr>
<th>Time:</th>
<th>Borlase's Machine</th>
<th>Hutchers</th>
<th>Difference in favor of Borlase's Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupied hutching cuttings</td>
<td>-</td>
<td>50 h</td>
<td>58 ( \frac{1}{2} ) h</td>
</tr>
<tr>
<td>Ditto; shifting sieve from do.</td>
<td>-</td>
<td>5</td>
<td>10 ( \frac{1}{2} )</td>
</tr>
<tr>
<td>Sludge machine, washing sludge and slime</td>
<td>-</td>
<td>21 ( \frac{1}{2} )</td>
<td>61 ( \frac{1}{2} )</td>
</tr>
<tr>
<td>Dressing the ore in a trunk</td>
<td>-</td>
<td>29 ( \frac{1}{2} )</td>
<td>61 ( \frac{1}{2} )</td>
</tr>
<tr>
<td>Aggregate number of hours occupied by the lads in doing the work, viz., feeding cuttings and hutching slime</td>
<td>111 ( \frac{1}{2} )</td>
<td>195 ( \frac{1}{2} )</td>
<td>84 h</td>
</tr>
<tr>
<td>Aggregate number of hours occupied by the lads in washing sludge and slime, including the final cleaning in a trunk</td>
<td>-</td>
<td>102</td>
<td>123</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost:</th>
<th>£ s. d.</th>
<th>£ s. d.</th>
<th>£ s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Of boys attending machine, wheeling away waste, and preparing ore for the bing-stead</td>
<td>1 15 9</td>
<td>2 8 9 ( \frac{1}{2} )</td>
<td>0 13 0 ( \frac{1}{2} )</td>
</tr>
</tbody>
</table>
ORES, DRESSING OF.

Produce:

<table>
<thead>
<tr>
<th>Produce</th>
<th>Sieve and Smidium Ore.</th>
<th>Sludge Ore.</th>
<th>Total Ore.</th>
<th>Total Lead.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borlase's machine</td>
<td>19 10</td>
<td>60</td>
<td>146.6</td>
<td>32 5.1</td>
</tr>
<tr>
<td>Hutches Difference in total</td>
<td>17 6.4</td>
<td>60</td>
<td>146.7</td>
<td>13 6.4</td>
</tr>
<tr>
<td>Ditto ditto</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Petherick's Separator. Figs. 489 and 490. A, the plunger or force-pump; b, receptacles fitted with sieves; c, hutch filled with water; d, discharge holes fitted with wooden plugs; e, movable plate to admit of withdrawing the ore; f, hopper with shoots for supplying sieves; h, beam for giving motion to plunger piston a; j, launder for delivering water to hutch.
About the year 1831, Mr. Petherick introduced the above machine at the Fowey Consols Mines in Cornwall. It was described in the Quarterly Mining Review, January, 1852, from which the following is extracted:—This machinery is particularly intended to supersede the operation of jigg ing in separating ores from their refuse or waste. * * * In the separators, the sieves containing the ores to be cleaned are placed in suitable apertures in the fixed coher of a vessel filled with water, connected with which is a plunger or piston working in a cylinder. The motion of the plunger causes the water to rise and fall alternately in the sieves, and effects the required separation in a more complete manner than can be performed by jigg ing. The variety in the extent and quickness of the motion required for the treatment of different descriptions of ores is easily produced by a simple arrangement of the machinery.

A principal advantage in this separator is derived from the sieves being stationary (in jigg ing, the sieve itself is moved) during the process; thereby avoiding the indiscriminate or premature passage of the contents through the meshes, which necessarily attends the operation of jigg ing, whether by the brake or hand sieve. Greater uniformity of motion in the action of the water, in producing the required separation, is also obtained; and superior facility afforded to the deposit in the water vessel (especially in dressing crop ores) of the finer and richer particles, which in jigg ing are principally carried off in the waste water.

The superiority of the patent separators over the ordinary means of cleaning ores will perhaps be best shown by reference to their actual performance. At the Fowey Consols and Lanecott mines in Cornwall, where they are extensively used, seventeen distinct experiments have been made on copper ores of various qualities from different parts of the mines, to ascertain the extent of the advantage of this mode of separation over the operation of jigg ing. Seventeen lots of ores, amounting together to about 300 tons, were accurately divided, one-half was jigg ed, and the other half cleaned by the separators. A decided advantage was obtained by the latter, in every experiment; the following are the aggregate results:

<table>
<thead>
<tr>
<th>Quantity of Marketable Ores returned.</th>
<th>Percentage of Metal.</th>
<th>Quantity of Metal.</th>
<th>Value of Ores.</th>
</tr>
</thead>
<tbody>
<tr>
<td>By jigg ing</td>
<td>76 19 0</td>
<td>75%</td>
<td>£ 362 15 7</td>
</tr>
<tr>
<td>By the separators</td>
<td>74 19 0</td>
<td>83%</td>
<td>£ 390 6 7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>£ 33 11 0</td>
<td>£ 2 11 4</td>
<td>£ 36 1 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Being £s. 8d. per ton, on 74 tons 19 ewt.</td>
</tr>
</tbody>
</table>

It must be obvious to those who are practically acquainted with the subject, that the poorer the stuff containing the ores, the greater must be the relative value of any improvement in the process of cleaning. This has been satisfactorily demonstrated by the trials which have been made in the mines before mentioned, in dressing the tailings, which are the refuse of the inferior ores, called halvans. It appears that these tailings may be dressed by the separators with more than treble the profit to the proprietors, which could be realized by the ordinary methods; and there is no doubt that there are vast quantities of surface ores, both copper and lead, in various mines, which might be dressed by the same means with considerable advantage.

Edward & Beacher's Patent Mineral and Coal-Washing Machine, consists of two cisterns, rectangular in horizontal section. Within a few inches of the top of these, perforated plates or screens, as fig. 491, are fixed, upon which the material to be washed is fed through a hopper, which also connects the two cisterns. On the inner sides of the cisterns are two apertures closed by flexible discs, or diaphragms of leather, as, when the machines are filled with water, cause it to rise and fall through a certain space, by means of a horizontal vibratory motion, which they receive from an eccentric on a shaft, which is driven either by a steam-engine attached directly to it, or by a driving-belt and pulley, as. See Washing Coal.

The action of the flexible diaphragms is similar to that of cylinders and pistons, which are sometimes substituted for them. Above the driving-shaft is a smaller one, a, which is driven at a slower rate by means of toothed wheels, and gives by eccentrics or eccentrics a horizontal motion backwards and forwards to sets of scrapers f, above the cisterns. These are so arranged as to remove the upper stratum of the substance being acted upon, and discharge it into wagons or other convenient receptacles; these upper strata are of course the lightest, the heavier part settling upon the perforated plates below.
When from the action of the machine a considerable quantity of material has accumulated upon these plates, the scrapers are thrown out of gear,分数 H, and the stuff raked off, the operation being then continued on fresh supplies. Doors, $\alpha$, at the bottom of the machines, admit of any fine stuff which may pass through the perforated plates being removed from time to time as may be necessary.

These machines are in use for cleansing coal as well as other mineral substances.

In such cases the heavier stuff which remains upon the plates consists of shale, pyrites, &c., very injurious substances in the manufacture of coke. The machine of two connected cisterns, is capable of washing about thirty tons per diem of coal, but the quantity of mineral work will depend upon the amount of ore present in proportion to the waste. The size of the perforations in the screens is adapted to the quality of the material acted upon.

A gold-washing machine has been arranged by Mr. John Hunt, late of Pont-Pean, France. This gentleman states that it requires but little water, and is so contrived as to circulate this water for repeated use; also that the principle would be found very successful if employed on a more extended scale; this Mr. Hunt intends to carry into operation at some lead mines in Cornwall.

Separators.

Of late years apparatus of this class has been steadily coming into operation, not only in lead and copper mines, but also in the dressing of tin ores. The prevailing principle is that of directing a pressure of water against the density of the descending material, making the former sufficiently powerful to float off certain minerals with which the ore may happen to be associated. When marked difference of densities exists, and the ore can be readily freed from its gangue, this mode of separation will be found effective. Trommels may be advantageously employed for sizing the stuff previous to its entry into the several separators.

Slime Separator.—This apparatus is due to Captain Isaac Richards, of Devon Great Consols, and is employed for removing the slime from the finely-divided ores which have passed through a series of sieves set in motion by the crusher. The finely-divided ores are for this purpose conveyed by means of a launder upon a small water-wheel, thereby imparting to it a slow rotary motion. Whilst this is turning, time is allowed for the particles to settle in accordance with their several densities; the result obtained is, that the heavier and coarser grains are found at the bottom of the buckets, whilst the lighter and finer matters held in suspension are poured out of the buckets and flow away through a launder provided for that purpose. The stuff remaining in the bottom of the buckets is washed out by means of jets of water obtained from a pressure-column ten feet in height, and passes directly into the tunnel of a round bundle.

The wheel a, fig. 492, is four feet in diameter, two feet six inches in breadth; has twenty-four buckets, and makes five revolutions per minute; b, launder for supplying the finely-pulverized ore; c, pressure-column; d, jet-piece; e, launder for conveying off the slime overflow of the wheel; f, launder for conveying roughs to round bundle. A modification of this apparatus is employed at the Wildberg mines in Germany, where it has been recently introduced, and is found to succeed admirably for the classification of finely-divided ores.
Ores, Dressing of.

Sizing Cistern.—The tails from round apparatus. It consists, fig. 493, of a wooden box provided with an opening at the bottom, a, which is in communication with a pressure-pipe, b, an outlet, c, and has a small regulating sluice, d. The stuff from the buddles enters at e, and the pressure in the columns is so regulated as to allow the heavier particles of the stuff to descend, but at the same time to wash away at f the lighter matters that may be associated with the ore. This is done by having the outlet c of less area than the inlet, and fixing on the extremity d a convenient regulating sluice, by which means a greater or less quantity of stuff may be passed over the depression r. Two cisterns of this kind are generally employed, the second being used to collect any rough particles that may have passed off from the first. The depth of the first of these boxes may be eighteen inches, its width thirteen inches, and its length three feet six inches. The dimensions of the second may be considerably less.

The arrangement of another separating box is shown in figs. 494 and 495. The slime water flows in at m; and water still holding a considerable portion of slime flows away from the opposite end. It is necessary that pieces of chip, small lumps, or other extraneous matter, should be intercepted previous to entering this apparatus, also that the slimes should be evenly sized by means of a trommel or sieve. The heaviest portion of the slime water in which the sand and ore are contained, is discharged at o, which is about an inch square. The launders p p are for the purpose of conveying the slime water either to buddles or shaking tables. The dimensions of the cistern No. 1 are, length, six feet; width, one and a half feet; depth, twelve inches. But two other cisterns of similar form are attached. No. 1 cistern will work about ten tons of stuff in twenty-four hours, and by widening the box from eighteen to twenty-seven inches, it will get through twenty tons in twenty-four hours. Affixed to one side of the boxes are hammers so contrived as to give thirty blows per minute in the manner of a dolly tub. The sides of the box have an angle of fifty degrees from the horizontal. The chief dimensions of the two cisterns, viz., one working ten and the other twenty tons, are subjoined.

<table>
<thead>
<tr>
<th>No. of Box</th>
<th>Ten tons.</th>
<th>Twenty tons.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length of Box</td>
<td>Breadth of Box</td>
</tr>
<tr>
<td>2</td>
<td>ft.</td>
<td>ft.</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>8</td>
</tr>
</tbody>
</table>
According to experiments made in the Stamping-house of Schemnitz, where twelve tons are stamped in twenty-four hours, the first cistern separated from the slimes 40 per cent. of the ore; the 2d cistern, 22 per cent.; the 3d cistern, 20 per cent.; the 4th cistern, 12 per cent.; together, 94 per cent., leaving a loss of 6 per cent. From No. 1 box every cubic foot of water flowing through gave 16 pounds of sandy matter. No. 2 afforded 13 pounds of finer stuff. No. 3, 16 pounds, and No. 4 yielded 12 pounds per cubic foot of water. It should be remarked that the outlet \( o \) is proportioned to the dimensions of the machine.

Borlase's Machine, fig. 496, has been recently introduced at the Allenheads Mines, belonging to Mr. Beaumont. The ore and mineral substances, after passing through the crushing apparatus, are introduced at \( A \), and flow through the spaces \( b b \), passing into \( c c \). At the bottom is a circular chamber \( e e \), with a perforated cylindrical plate \( r \). Water under pressure is supplied by the pipe \( g \), and regulated by the cock \( h \).

It will be seen that this apparatus consists of an external and internal cone with a space between them, and that a separation of the orey matter is effected by limiting the power of the water between the density of the stuff to be retained, and that which is to be discharged at \( j j \) into the shoot \( k \).

At \( l \), the larger and denser portion of the mineral which has fallen through the ascending current of water, is conveyed either to a jiggering machine or some other enriching apparatus. Mr. Borlase first erected this apparatus in the United States of America, where it was found to answer remarkably well, and he was induced by this success to attempt its general introduction in this country. In this endeavor he has not, however, been as yet so entirely successful as could be wished, as the English mines, and particularly those of Cornwall, are for the most part managed by individuals who require to be fully convinced of the utility of any new invention before giving it a trial. This machine has been employed with great success at the mines of Allenheads. The comparative results afforded by Borlase's Trunking Machine and the common Nicking Trunks may be seen from the following statistical statement.
LEAD MINES, ALLENEADS.

Results of trials with Borlase’s 4 1/2 feet Circular Lead Ore, Sludge, and Slime Dressing Machine, and the common Nicking Trunks, March, 1859. Forty-four wheelbarrows full of exactly the same description of slimes were put through each of the respective processes.

<table>
<thead>
<tr>
<th>TIME</th>
<th>Borlase’s Machine</th>
<th>Trunks</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours</td>
<td>Minutes</td>
<td>Hours</td>
<td>Minutes</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>52</td>
<td>16</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>£</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRODUCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td>109</td>
</tr>
</tbody>
</table>

* The cost is unduly heavy, the same value of labor would have maintained three machines.
Fig. 497 represents a wooden cistern \( \alpha \), having an aperture \( n \) at the bottom, about an inch diameter, which is alternately closed and opened by means of an iron plate \( c \), fitted upon the vertical shaft, to which is also fixed an iron paddle \( n \), which revolving horizontally keeps the ore and water in constant agitation. The tails from the various puddles, as well as the stuff from the cofers at the end of the strips, flow in at \( e \), and pass through a perforated sizing plate \( \gamma \), into the cistern. The rougher and heavier portions escape through the hole \( n \) into a strip where it is continually stirred, in order that it may be evenly deposited, and at the same time freed from the lighter particles. The overflow containing fine ores passes by the launder \( g \) into catch pits, from which heads and middles are taken to be elaborated by means of puddles or other apparatus. When this separator is employed in tin dressing, it is usual to divide the stuff in the strip connected with the bottom of the box, into heads and tails. The first is taken direct to the stamps, and again pulverized with rough tin stuff; but before the tails can be so treated, they are re-stripped in order to get rid of extraneous matter.

Wilkin's Separator.—This apparatus is the invention of Mr. J. B. Wilkin of Wheal Basset and Grylls, near Helston. He describes it as a "self-factoring tossing-machine, by which the rough particles are separated from the fine and prepared for the inclined plane. The orey matter is carried into a small cistern by a stream of water which enters at the top and passes out at the opposite side bearing the finer particles with it, whilst the rougher and heavier particles escape at the bottom through a rising jet of clean water, which prevents the fine and light particles from passing in the same direction." \( \alpha \), fig. 499, inlet of clean water; \( n \), launder delivering the orey matter; \( e \), outlet of fine and inferior stuff; \( h \), discharge orifice for rough and heavy stuff. This operation must be regulated by a flood-shut. A cistern 10 feet square on the top, and 18 inches deep, will pass through about 40 tons in 10 hours. When separating stamps work a smaller cistern is employed, say 14 inches square, 10 inches deep; this will despatch 6 tons in 10 hours.

A valuable form of separator is shown in fig. 500, the peculiarity of which consists in the manner of introducing the water and slimes. Instead of the latter depending for separation upon the power of an ascending column of water, it here passes into a horizontal flow of greater or less volume and velocity, produced by altering the tap \( \alpha \). Compartments, viz., 1, 2, 3, and 4, are also fitted in the box, for the purpose of receiving mineral of different densities and size, which is discharged and washed in strips set underneath; \( \lambda \), inlet launder to trommel; \( n \), waist of sheet-iron; \( c \), trommel either of perforated plate, or wire gauze; \( \eta \), shoot from trommel serving to convey away the rougher portions; \( f \), hopper for conveying stuff to shoot \( n \), and from thence into the box; \( \beta \), ascending column of water; \( \gamma \), tap for regulating the flow of water; \( \kappa, \lambda, \mu, \nu \), outlet pipes for delivering the
ORES, DRESSING OF.

separated stuff to strips or buddies; \( \text{o} \), launder for receiving overflow from cistern; \( \text{p}, \text{q}, \text{r} \), valves regulating the width of the compartments, also for the purpose of effecting the disposition of the different minerals with which the ore may be associated.

In addition to the machines already described, a slime or sludge-dressing apparatus has been designed by Mr. Borlase, and which he intends to introduce into the mining districts of this country. *Fig. 501* represents an elevation, and *fig. 502* a plan of this machine.

It is described by the inventor as follows:—The mineral from which it is desired to separate the metallic ore having been crushed or pulverized, is conducted through a pipe or channel into a revolving cylindrical sieve, \( \text{A} \). The larger parts pass into a shoot or launder, \( \text{n} \), and from thence into a self-acting jiggling machine. The slime or fine portion passes through the meshes of the sieve into a shoot, \( \text{c} \), and is discharged into an annular launder, from whence it falls either into a stationary or revolving distributor, \( \text{d} \). From thence it
ORES, DRESSING OF.

flows through suitable channels into the outer part of the machine, k. The apparatus is fixed on a perpendicular axis, f, and is kept in a continual oscillatory motion by means of cranks and connecting rods, a, the speed of the cranks being adjusted so as to keep the slime in continual motion, and at the same time cause the ore to descend and deposit itself at the bottom, whilst the waste or lighter portion is carried towards the inner part of the machine, where it passes over a movable ring, n, which is raised mechanically, and in proportion as the ore rises in the apparatus. The waste is discharged through the outlet, r, and conveyed away in launders. When the machine is filled with ore, it can be settled, as in the dolly machine, by means of percussive hammers, p, p. The ore can be collected either by reversing the gear and lowering the ring, n, or it may be washed into a receiver as convenient.

Motion is given to the vertical bar, k, which is made to vibrate so as to turn by means of a ratchet the wheel, i, fitted on a horizontal shaft, m. The ratchet is raised or lowered by a worm screw, in order to increase or decrease the speed rendered necessary by the quality of ore operated upon. On the horizontal shaft, m, is a worm pinion, which works a wheel on a perpendicular shaft, n, on which is fixed a second worm pinion, raising or lowering the tooth segment on the end of the beam, o. This segment can be shifted out of gear. The opposite end of the beam, o, is attached to the rod, r, and connected with the cross-bar, n, as also with the ring, n, which has a reciprocatory motion in the centre of the perpendicular shaft, f.

From the foregoing description it would appear that Mr. Borlase has combined in this apparatus the principles of the round bubble with that of the dolly tub.

In the year 1857, Herr Von Sparre, of Elschen, Prussia, patented four machines for separating substances of different specific gravities, in all of which water is employed, either as a medium through which the said substances fall under the action of gravity, or as an agent for facilitating the motion of portions of the said substances along inclined surfaces. The particulars, together with illustrations, will be found in patent No. 1403 for the year 1857.

The mechanical preparation of tin and copper ores has from time to time been noticed by several writers. In 1783 Borlase described the method employed in the west of Cornwall. Twenty years later, Price, in his Mineralogia, added to Borlase's description, and illustrated some of the apparatus then in use. Afterwards Dr. Bose published, in the second volume of the Transactions of the Geological Society of Cornwall, an article upon the dressing of tin in St. Just. In Vol. IV. Mr. W. Jory Henwood inserted a paper on dressing and some general remarks will be found on the subject in De la Bèche's Report on the Geology of Cornwall. The enrichment of lead ores has been noticed by Forster, in his Section of Mineral Strata; also by Warington W. Smyth, in his memoir On the Mines of Cardiganshire, in the second volume of the Memoirs of the Geological Survey of Great Britain.
ORES, DRESSING OF.

In France, Dufreney and Elie de Beaumont, Coste, Perdonnet, and Moissenet, have treated on the mechanical enrichment of copper and tin ores. The latter gentleman visited this country in 1857, and subsequently gave the results of his observations in a highly interesting memoir, entitled *Préparation de Minéral d'Aluine dans le Cornwall*. Too much attention cannot be given to this section of mining economics, for with the increasing production of ores, especially of ores of low produce, and the ill-adapted machinery oftentimes employed, the loss in concentrating them is an item of most serious moment, any reduction of which will be so much positive gain to the country.

In this paper we have included those machines which have been long employed in our metalliferous mines—many of them having been proved by experience to be most economical—together with such of the modern introductions as appear to promise the most advantage, and some suggestions which cannot but be valuable, since the principles involved are founded upon the universal laws of gravitating power, as applied to solids and fluids in motion.

The Strake, Tye, and Strip.

These appliances may be considered modifications of each other. Instead of effecting a separation by relying upon subsidence according to the specific gravity of the substances, they are mechanically impelled against a volume of water so regulated as to carry off the lighter particles.

*Fig. 503* represents a ground plan of a strake employed in the lead mines of Wales.

Its extreme length is about 18 feet, width 3 feet. The top increases from 18 inches to 2 feet 9 inches wide. It is constructed of wood, the bottom being covered with sheet-iron.

The tye is usually 20 feet long, 2½ feet wide, and is often employed for cleaning hutch-work. In some instances when the ore or dradge is very rich, it is crushed and then tyed into heads, middles, and tails, the first portion going to pile, the middles re-tyed, and the tails treated as refuse washed in the bundle.

*Fig. 504*, a, inflow of water; b, head of tye; c, partition board. The stuff is intro-

duced into the cistern d, flows over the inclined front e, and is broomed at f. Between e and o are the heads, from o to n middles, n to t, tails. At k is an outlet launder regulated with a flood shut. An outline plan of the tye is shown, *fig. 506*.

The strip also consists of a wooden box with its bottom inclined at a greater or less angle, in order to suit the character of the stuff to be operated upon. The object of this apparatus is somewhat analogous to the separating box, viz., to deprive the ore of the fine particles with which it may be associated, and thereby to enrich it for subsequent treatment. A rather strong stream of water is employed against which the mixed mineral is violently projected by means of a shovel. When ores are strong and clean in their grain, but little loss can occur from this process, provided proper care be exercised in conducting it; but if their structure be delicate and the constituents intimately mixed, the wastage must necessarily be great.

The illustration, *fig. 506*, shows a strip, cofer, and settling cistern, with filtering apparatus contrived for lead ore. a, vertical launder 6 inches square, delivering water into the box n, 9 inches long by 20 inches wide at the point c; n, bottom of strip covered with
ORES, DRESSING OF.

sheet-iron, 6 feet long and 16½ inches wide at k. At this point a ledge of wood is sometimes introduced for the purpose of modifying the velocity of the water and forming a kind of shallow reservoir, so as to allow the workman to stir the stuff. At the end of the strip a caught, y, is fixed, 11 inches deep, 30 inches square; u, settling box, 6 feet long and 30 inches deep; k, outlet for waste water. At g is inserted a filtering launder, 13 inches deep, extending across the cistern. At j a similar launder is placed, about 9 inches deep. The water comes in at a, is lodged in cistern b, flows smoothly over the feather-edged board c, falls into p; here the orey matter is exposed to its action, a portion settles in r, the flourin and other light waste then descends through a, depositing itself in the box n; and to retain the valuable products as much as possible, it is filtered at j, through a perforated plate covering the bottom of the launder. In stripping, care must be taken to regulate the overflow of water at c; rough stuff must be subjected to a stronger current than finer matter, and the bottom of the strip should be constructed with a greater inclination. In some lead mines the buddle and hutch-work is stripped to be re-jigged, whilst the stuff resulting from the filtering box is hand-buddled until sufficiently enriched for the dolly. When ore is associated with a heavy matrix, and the grain breaks into a lesser size than the other particles, the stripping may be performed by inversion, that is, to wash the orey product into the cover and filtering hutch, retaining the worthless portions at b.

The flat buddle, fig. 507, is a modification, peculiar to the Welsh mines, of the inclined plane, and different from all others in its very trifling inclination.

The stuff is placed in a small heap on one side of the supply of water, and drawn with a hoe partly against and partly across the stream to the other side of the buddle, losing in its passage all the lighter parts. A heap of ore treated in this manner may be deprived of a portion of blende and pyrites, minerals which from their high specific gravity may have resisted previous operations. a, platform of boards inclined two and a half inches in seven feet; b, catch-pit two feet deep. The width of this buddle varies from ten to twelve feet.

Lisburne Machine.—This apparatus was invented by the agents of the Lisburne Mines, Cardiganshire, and has been most successfully employed in separating blende from lead ores. Fig. 508 represents an elevation, and fig. 509 a ground plan of this machine. n, rakes or
ORES, DRESSING OF.

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scrapers set at an angle, depending from rods having their axis of motion on the arbor e. This arbor, as well as a parallel one, is carried on friction rollers o o, and so braced together as to form a kind of frame. m, rod attached to frame, and connected with water-wheel L. s, balance-beam, counterpoising the frame, and rendered necessary in order to equalize the motion. P P', balance catches serving to support the third arbor when elevated. This arbor is also parallel to the other two, but has its position on the top of the guide frame shown in the elevation. It passes immediately under the angle of the L-shaped rods, and is mounted on friction wheels. Its action is as follows. When the scrapers have nearly completed their ascending stroke, this arbor is elevated by means of the wedge-shaped projection on the top of the frame, and immediately the balance catch acts so as to retain it in this position during the descending stroke, at the termination of which the catch comes in contact with the projecting screw shown in the elevation, thereby dropping the scrapers upon the face of the muzzle. Consequently, in the ascending stroke, these scrapers plough the vein stuff against the flow of the stream. The heavy matter to be operated upon is introduced into the compartment shown on the top of the plan, and by means of the diagonal scrapers it is washed and passed slowly across the table, the heavier portion being delivered into the bin r, and the lighter matter into the box z, whilst the tails are lodged in the strips h h. The water employed in driving the wheel is also used for the muzzle; one portion of it serves to introduce the ore, whilst the other is regularly diffused over the surface of the ore by means of two large sprinklers arranged under the table, so as to keep the water and dust in state of suspension, whilst the bin is to be sufficient cleaned for the market. The cost of this apparatus complete is about £50.

SAND AND SLIME DRESSING MACHINERY.

In most mines a large proportion of the ore is composed of drudge, and has to be brought to a fine state of subdivision either by the crushing-mill or stamp. In this condition the ore is freed from sterile matter, and rendered fit for metallurgical treatment. A variety of machines have been invented and applied to this division of dressing, in which the leading principle is to produce a separation by turbulence, according to the density of the substances. In connection with this principle, the stuff is not permitted to have a vertical fall, but is traversed by a flow of water, on a table or bed set at such an angle to the horizontal plane as may be found expedient. With extremely fine stuff apparatus, including both of these features, are sometimes subjected to a mechanical jar or vibration, so as to loosen and eject, as it were, the worthless matter with which it may be charged. In concentrating crushed or stamped ore, a certain quantity will often exist in a very minute state of division, unable to withstand the currents and volume of water necessary for the separation of the larger particles.

The amount and richness must necessarily depend upon the united produce and character of the ore, as well as the mode of treatment observed. A good dresser will form as little slime as possible, since when the ore is brought to this condition it is usually associated with a large mass of worthless matter; and not only so, but the expense of extracting it is materially increased. The loss under the most favorable manipulation is very large, whilst the machinery requisite is probably more complicated and expensive than any other section of the dressing plant. Although several machines are illustrated under this head, and many more might have been added, it does not follow that they may be advantageously employed for every variety of ore.

Thus an apparatus which would enrich slimes by one operation from 1 to 5 per cent., might be both economical and desirable for treating copper ore, but would not be so important in the case of lead ore of the same tenure; for after deducting the loss of metal incident to the enrichment, charging the manipulative cost on the full quantity of stuff, and estimating the relative value of the two products, it might be found that one would scarcely leave a margin of gain, whilst the other would yield a satisfactory profit.

The preparation of slime is as necessary as in the case of coarser work, and for this purpose Captain Isaac Richards, of the Devon Consols Mine, has arranged a peculiar slime-pit. The water and stuff from the slime separated, are delivered through a launder into this pit, at the head of which is fixed a slightly inclined plank, divided into channels by slips of wood set in a radial direction from the aperture of the delivery launder. This pit has the form of an inverted cone, and since the water passes through it at a very slow rate, the more valuable and heavier matters will be deposited at the bottom. This apparatus thus becomes not only a slime-pit, but also a slime-dresser.

The ordinary slime-pit has usually vertical sides and a flat bottom; the slime and water enter it at one of its ends by a narrow channel, and leave from the other by the same means.
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A strong central current is thus produced through the pit, which not only carries with it a portion of valuable slime, but also produces eddies and counter-currents towards the sides, which have the effect of retaining matters which from their small density should have been rejected.

The improved pit, fig. 510, receives its slimes from the divided head n, and lets a portion of them off again at c, whilst the richer and heavier matters, which fall to the bottom of the arrangement, escape through the launder m, and are regulated by means of the plug a, and the regulating screw a'.

At Devon Consols the slimes flowing from the launder n are directly passed over Brunton's machines, but instead of these sleeping tables may be employed.

In many cases sand and slime stuff are much commingled with clay, and require to be broken and disintegrated before the ore can be extracted. A method for accomplishing this is shown in fig. 511. a is the circumferential line of a round buddle; b, launder leading to such buddle, or any other enriching apparatus; c, sifting trommel; d, rotating paddles; e, tormentor; f, driving shaft.

A modification of this method is found in the slime trommel, fig. 512. a, hopper, into
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which slimes are lodged; h, launder, delivering clean water into hopper a; c, trommel of sheet-iron, fitted in the interior with spikes for the purpose of dividing the stuff; v, disc, perforated to prevent the passage of pieces of chips or bits of clay and stone; r, Archimedian pipes fitted into a disc of sheet-iron, conveying water into gauge or perforated trommel f; g, slime cistern; h, cistern for receiving the rough stuff; j, slime outlet, communicating with round buddle, or other suitable apparatus; k, outlet for trommel raff, which may be delivered to a sizing cistern. The speed of the gauge trommel for fine slimes varies from 80 to 100 feet per minute.

Hand Buddle.—This apparatus is somewhat extensively employed in lead mines for the concentration of stuff which contains but a small proportion of ore, such as middles and tails resulting from the round buddle, or the tails from strips, &c. A rising column of water is shown at a. This flows into a trough b, and through peg-holes into c. Here the stuff to be treated is introduced, and continually agitated by the boy in attendance. The finer portion passes through the perforated plate at a, and is distributed by the fan-shaped incline k in a uniform sheet on the head of the biddles. A boy stands just below the higher line of middles with a light wooden rake; with this instrument he continually directs the descending current to the head of the buddle, and by this means succeeds in separating a larger proportion of the ore than would otherwise be done. Whether the rake or the broom be employed, it is found that some of the fine lead is removed to the extreme tail of the buddle. In order to prevent this, the frame g has been introduced. It is strained with canvas, and always floats on the flooded water. This canvas retains the fine lead, which is from time to time washed off in a cistern of water. The section to the first dotted line shows the heads of the buddle; from this to the second dotted line will be the middles, and from the second dotted line the tails commence. It must, however, be remarked, that the exact line of heads, tails, and middles, must depend upon their relative richness. The wooden rake is undoubtedly preferable to the broom, as will appear from the following experiment made at the Swanpool Mines, every thing being equal in both trials.

Stuff operated upon; tails from washing strips assayed 13 per cent.

<table>
<thead>
<tr>
<th>No.</th>
<th>Heads, assayed</th>
<th>With Broom</th>
<th>With Rake</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>16 ¾</td>
<td>20 ½</td>
</tr>
<tr>
<td>2</td>
<td>Middles, ditto</td>
<td>44</td>
<td>54 ½</td>
</tr>
<tr>
<td>3</td>
<td>Tails, ditto</td>
<td>42 ½</td>
<td>1 ½</td>
</tr>
</tbody>
</table>

It would be found a great improvement if these biddles were arranged so as to have their bottoms elevated when it might be necessary. As they are fitted at present, the angle at the head is a constantly increasing one. The result is, the heads become poorer and the tails richer, provided the fixed inclination of the buddle is correct at starting, as the operation proceeds. In proportion to the poorness of the stuff the buddle should have its width increased, as well as be made shallower. If the stuff be also passed through a trommel before entering the buddle, the result will be found much improved.

The Round Buddle is said to have been first introduced into Cardiganshire, but has now become general in every important mining district. This machine serves to separate particles of unequal specific gravity in a circular space inclined from the centre towards the circumference. Its construction will be best understood by reference to the annexed engraving, fig. 514, in which a is the conical floor, formed of wood, and about 18 feet in diameter, on which the stuff is distributed; b is a cone supporting the upper part of the apparatus, and serving to effect the equal distribution of the ore matter. c is a wheel for giving motion to the arrangement; d, a funnel perforated with four holes and furnished at top with an annular trough; ef are arms carrying two brushes balanced by the weights g h; i is a launder for conducting the stuff from the pit; k is a receptacle in which the slimes mixed with water are worked up in suspension by the tormentor, which is a wooden cylinder provided with a number of iron spikes; l is a pulley taking its motion from a water-wheel, and
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A circular sieve fixed on the arbor \( x \). The stuff at \( k \) is gradually worked over a bridge forming one of the sides of a catch-pit between the sieve \( m \) and the tormentor, from whence it passes off into the sieve, by which the finer particles are strained into the pit \( i \), whilst the coarser, together with chips and other extraneous matters, are discharged on the inclined floor in connection with the launder \( o \). From the pit \( i \) the stuff flows by the launder \( n \) into the funnel \( k \), and after passing through the perforations flows over the surface of the fixed cone \( a \), and from thence towards the circumference, leaving in its progress the heavier portions of its constituents, whilst the surface is constantly swept smooth by means of the revolving brushes. By this means the particles of different densities will be found arranged in consecutive circles. The arms usually make from two and a half to four revolutions per minute, and a machine having a bed 18 feet in diameter will work up from 15 to 20 tons of stuff per day of ten hours.

German Rotating Buddle.—This machine is said to effect the separation of the earthy matters from finely divided ores more readily than the ordinary round buddle. For this purpose the pulverized ore is introduced near the centre of a large slightly conical rotating table, and flowing down towards its periphery a portion of the upper part or head becomes at once freed from extraneous substances. Beyond this line of separation in the direction of the circumference, the stuff is subjected to the action of a series of brushes or rakes, and by means of a sheet of water flowing over the agitated slime, clean ore is stated to be produced almost at a single operation.

The illustration, fig. 515, represents this machine as first erected at Clausthal, but it may be remarked that some of its mechanical details have been since judiciously modified by Mr. Zenner of Newcastle-on-Tyne. \( A \) is an axis supporting and giving motion to the table \( n \), 10 feet in diameter, and rising towards the centre 1 inch per foot; \( c \), cast-iron wheel 13 inches in diameter, operated on by the tangential screw \( b \). The tooth-wheel \( v \) drives the pinion \( f \), the axis of which is provided with a crank giving motion to a rod fitted with brushes; \( o \) is an annular receiving-box 4 1/2 inches wide, and 6 inches deep; \( e \), circular trough of sheet-iron supported on the axis of the table an inch or two above its surface, and so divided that one quarter of it serves for the reception and equal distribution of the slime, whilst the other three-quarters supply clear water; \( h \), launder for supplying slime ore, behind which is another not shown, for bringing in clear water. \( o \), trough supplying additional water to the stuff agitated by the brushes. One end of this water-trough is fixed about the middle of the table, whilst the other advances in a curved direction nearly to the circumference.

The Concave Slime Buddle.—The object of this apparatus is to concentrate on the periphery of the floor, instead of the centre. This arrangement gives an immense working
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The area for the heads, and at the same time admits of the separation of a greater portion of the waste than can be effected by the ordinary round buddle. After the slimy water has been discharged on the edge, the area over which it has to be distributed is gradually contract-

ing, thereby increasing the velocity of the flow, and enabling it to sweep off a proportionate quantity of the lighter matter associated with the ore. \( a \) represents the inflow slime launder; \( b \), a separating trommel, through which the slimes pass previous to their entrance into the launder \( a \). \( c \), outlet launder, for taking off castaways; \( d \), arbor giving motion to the buddle arms and diagonal distributing launders attached thereto held by the braces \( w \); \( e \), bevel wheel on driving arbor; \( f \), downturn lauder, to which is affixed a regulating cock, \( k \), for supplying slimes to trommel; \( h \), lauder for delivering clean water to circular box \( m \), and which water passes through slot openings at \( p p \), uniting with and thinning the slimy matter previous to its passing into the diagonal delivery launders; \( l \), circular pit for receiving tailings. Attached to the wooden bar \( x \) is a piece of canvas with corresponding pieces depending in a similar manner from each arm, and which serve to give an even surface to the stuff in their rotation. The slimes flow from four diagonal launders, each having its upper end in communication with box \( l \). The speed of the arms and diagonal launders must vary with the nature of the stuff to be operated upon; for rough sands eight revolutions per minute have been found sufficient, but for fine slimes from fourteen to sixteen revolutions in the same time are necessary. The inflow of slime and water should also be proportioned to the speed and density of the stuff to be treated. No precise instructions can be offered on this head, but an experienced dresser would easily determine the proportions after a few trials. The bed is eighteen feet diameter, and has a declination of about six inches from the edge to the point where it unites with the horizontal portion of the floor. The cost of this apparatus complete is about £15. It is employed to a considerable extent in Prussia, and affords highly satisfactory results.

Experiment on slime ore, very fine and much intermixed with carbonate of iron:

 Produce before entering buddle : 6 per cent.

 Heads of buddle averaging 3 inches deep \( \frac{1}{2} \) to \( 12 \frac{1}{2} \) inches and \( 30 \) oz. of silver per ton of lead.

 Middles of buddle averaging 1 \( \frac{1}{2} \) inches and \( 18 \) inches wide \( \frac{3}{4} \) and \( 42 \) oz. " " "

 Tails of buddle averaging \( \frac{1}{4} \) inch deep \( \frac{3}{4} \) and \( 55 \) oz. of silver per ton of lead.

 Castaways \( \frac{1}{4} \) per cent.

 Time required to fill buddle, 3 hours; number of arms in buddle, 4; number of revolutions of arms per minute, 8.

Experiment on fine slimes, much associated with carbonate of iron:

 Produce before entering the buddle : 3 per cent.

 Heads 3 inches deep, 10 inches wide \( 3 \) per cent.

 Middles 1 \( \frac{1}{2} \) do. 12 do. \( 7 \) per cent.

 Tails \( 1 \) per cent.

 Number of revolutions of arms per minute, 14; time required to fill buddle, 5 hours.
In working thus buddle one month upon the fine and rough slimes, indicated in the two foregoing experiments, the results obtained were:

<table>
<thead>
<tr>
<th>Assay of stuff before entering the buddle</th>
<th>Heads afforded</th>
<th>Middles</th>
<th>Tails</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>50^\circ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heads afforded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middles</td>
<td>125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tails</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:77</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Experiment on slime ore containing 20\% per cent. of lead:

In 12 hours 2.4 tons were washed, and gave 14 cwt. of crop, 28 cwt. middles, 12 cwt. tails, and 16 cwt. of waste. The 14 cwt. of crop were washed in 3 hours, and afforded 5\% cwt. of each crop, 5\% cwt. of middles, 4 cwt. of tails, and 1 cwt. of castaways. The middles resulting from both operations, viz., 33\% cwt., were washed in 8 hours, and gave crop 4 cwt., middles 12 cwt., tails 4 cwt., and waste 2.5\% cwt. The tails were now washed in 8 hours, and afforded 4 cwt. of middles and 12 cwt. of castaways, 10 cwt. of middles were also washed in 3 hours, and furnished 2 cwt. crop, 6 cwt. middles, and 8 cwt. of castaways. In addition, 10 cwt. of crop were washed during 3 hours, and gave 1\% cwt. of slime ore, crop, 1 cwt., middles, 6 cwt., castaways, 1 cwt.

The results, therefore, show that 4 tons of rough slime were washed in 32 hours, and afforded 5\% cwt. slime ore at 45\% per cent., 21 cwt. of crop at 61 per cent., and 12 cwt. of middles yielding 44\% per cent. A comparison was also made with the shaking table; 5 tons of the same slimes were washed in 48 hours, and gave 7 cwt. of dressed ore, 1 cwt. of heads, and 8 cwt. of middles.

The following are the results of an experiment made between the concave buddle and the ordinary round buddle, time occupied, 24 hours:

<table>
<thead>
<tr>
<th>Pounds</th>
<th>Water, Weight per cent.</th>
<th>Dry Weight</th>
<th>Lead, Assay per cent.</th>
<th>Tails, Assay per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of slimes to each buddle -</td>
<td>4262</td>
<td>50%</td>
<td>3268</td>
<td>8%</td>
</tr>
<tr>
<td>Obtained from concave buddle -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crops -</td>
<td>50%</td>
<td>6%</td>
<td>25%</td>
<td>10%</td>
</tr>
<tr>
<td>Middles -</td>
<td>15%</td>
<td>6%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Total -</td>
<td>15%</td>
<td>6%</td>
<td>25%</td>
<td>10%</td>
</tr>
<tr>
<td>Obtained from round buddle -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crops -</td>
<td>51%</td>
<td>2%</td>
<td>20%</td>
<td>4%</td>
</tr>
<tr>
<td>Middles -</td>
<td>5%</td>
<td>2%</td>
<td>10%</td>
<td>6%</td>
</tr>
<tr>
<td>Total -</td>
<td>53%</td>
<td>2%</td>
<td>20%</td>
<td>4%</td>
</tr>
<tr>
<td>Loss by concave buddle -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>do, round do. -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The tails lying upon the horizontal part of concave buddle contained 27\% per cent. of zinc and 2\% per cent. of lead.

It will be perceived that the much larger crop from the concave buddle was more than twice as rich for lead, whilst it was only 2 per cent. richer for zinc.

Quartzose ore without blende was then tried, and a similar weight gave 1,570 lbs. of crop, affording 5\% per cent., or 888 lbs. of lead, and 3,400 lbs. of middles, of 14 per cent. produce, equal to 485 lbs. of lead, or together 5,020 lbs. of stuff, containing 1,572 lbs. of lead. The round buddle, on the contrary, gave 455 lbs. of crop ore, of 5\% per cent., equal to 290 lbs. of lead, 2,910 lbs. of middles, of 16\% per cent., representing 511 lbs. of lead, or a total of 3,505 lbs. of stuff, containing 851 lbs. of lead.

Fig. 517 represents a buddle arranged for the treatment of fine slimes, and which has been found to yield highly satisfactory results at several mining establishments in Prussia where it has recently been introduced. It is entirely constructed of metal, and every part is carefully fitted in order to secure an even and delicate action. The stuff is introduced into the hopper a, from whence it passes into the trommel b, turned by the band c. The fine stuff passing through the perforated cylinder d, falls upon the shoot e, and flows upon the concave table f. This table revolves in the direction of the arrow, and acquires its
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motion by means of the strap $o$ driving the tangent wheel and screw shown at $n$. Concen-
tric with the table a wrought-iron pipe, $i$, is fixed, which is pierced with numerous small holes. The quantity of water to this pipe is adjusted by the regulating cocks $j' j''$. Be-

neath the table is a circular receptacle or bottom, $k$, having three compartments for receiv-
ing the washed stuff. From $a$ to $d$ the jets of water are comparatively light; from $d$ to $e$
the force of water is increased, and still further augmented in that portion of the circle extending from $e$ to $o$, whilst from $o$ to $i$ it is sufficiently powerful to clean the buddle. In
each of the sections a portion of waste along with a little light ore is washed into the recep-
tacles underneath, from whence it may flow into strips or buddles for further separation, or
is otherwise manipulated upon a second buddle. The water is supplied to the machine
under pressure by the pipe $l$. This apparatus will wash from 80 to 100 cubic feet of free
slimes in ten hours, or from 60 to 80 cubic feet of tough slimes in the same period. Lead
stuff affording 4% with a light waste has been enriched to 40% in a second revolution, and
in a third and fourth rotation 40% slime has been enriched so as to yield 60% of ore. The
buddle table makes two revolutions per minute; its diameter varies from 8 to 10 feet, and
the power required is about one-tenth of a horse power. One boy can serve four buddles.

Slime Trunking Apparatus.—The illustration fig. 518 shows the apparatus employed in
some of the lead mines of Cardiganshire. The slimes are lodged in the several settling
pools marked $A$, and flow through the channels $B$. At $c$ the slimes pass into the launder $p$
to the box $x$, where they are comminuted, and from thence progress into the trommel $e$. From the circular sixtarn $g$, V-shaped launderers diverge to the trunks $k$, which are divided
by partitions $t$. Upon the axis $i$ in each buddle head, paddles rotate, and flush the slimes
over a head board, where a partial separation is effected. The wheel $l$ is driven by water
from the pools $A$, and any excess is carried off by the launder $x$. At $o$ or two hand-buddles
are shown; these are intended for the concentration of the heads and middles produced in
the trunks $k$. The axis at $r$ is furnished with spikes for the purpose of breaking up the
slimes. After the water has passed over the wheel $l$, it flows into the launder $x$, and from
thence into $q$.

At the Minera lead mines, where the ore produced is very massive and capable of a high
degree of enrichment, the slimes average 9 per cent., and are concentrated, by means of
this apparatus, together with a round buddle and dolly tub, to 75 per cent. of metal. With
six trunks, one round buddle, one man, and four boys, about nine tons of clean ore are ob-
tained monthly.

Attempts have been made by Brunton and others to separate metalliferous ores of dif-
ferent specific gravities by allowing them to descend at regulated intervals in still water.
By reversing the operation and causing the current to ascend uniformly, the particles may
be much more conveniently and accurately classified. This has been done in a machine
designed by the late Mr. Herbert Mackworth. Suppose a funnel-shaped tube, larger at the top; with a current of considerable velocity flowing upwards through it, grains of equal size of galena, pyrites, and quartz, when thrown in, will be suspended at different heights, depending on the velocity of the current at each height. Thus cubical grains of galena, iron, pyrites, and quartz, of $\frac{1}{12}$ inch diameter, will be just suspended by vertical currents moving at velocities of 12 inches, 7 inches, and 5 inches linear per second; flat or oblong particles require rather less velocities to support them, inasmuch as they descend more slowly in still water than the cubical or spherical particles.

A simple form of applying this principle is presented by the vertical trunks shown in figs. 519 and 520. Metalliferous ore, after being classified by sifting, or tin ore as it comes from the stamps, may be allowed to flow mixed with water down the shoot $\lambda$. The supply
of water should be taken from a head so as to be perfectly uniform in quantity. The water mixed with the ore flows in the direction of the arrows down and then up the divisions n', n', n', n', and n', each of which increasing in area, the velocity of the ascending current diminishes in the same proportion. The particles of greatest specific gravity will be de-

posed in the bottom of n'. In the bottom of n' will be found small particles of great specific gravity and large particles of small specific gravity. The same relation will exist in n', n', and n'; only the particles of each will be smaller in succession. The plugs in the holes c c c, being opened as is found necessary, allow the accumulations in the bottom of each trunk to discharge themselves into separate troughs. The rocking-frame and rakes d d constantly stir up the sediment so as to bring it under the action of the water. To produce the oscillation of the rakes, two spade-shaped plates k k are exposed to the action of the falling water discharged from the end of the box which rocks the frame to and fro. The ore in the first trunk is fit for smelting; the ore passing off from the bottom of the other trunks is in a very favorable condition for framing, or it may be sifted to remove the larger particles of less specific gravity.

The Rack or Hand-Frame.—This is composed of a frame c, fig. 521, which carries a

sloping board or table susceptible of turning to the right or left upon two pivots k k. The head of the table is the inclined plane r. A small board r, which is attached by a band of leather t, forms a communication with the lower table c, whose slope is generally 3 inches in its whole length of 9 feet, but this may vary with the nature of the ore, being somewhat less when it is finely pulverized.

In operating with the table, the slimy ore, to the extent of 15 or 20 pounds, is placed on the head r, and washed over L and P on to the table; then the operator with a toothless rake distributes it equally over the head, the richest particles remain on the highest part of the table by virtue of their greater specific gravity, whilst the muddy water falls through a cross slit at the bottom into a receptacle a. When the charge of ore has been thoroughly racked, the table is turned on its axes k k until it is brought into a vertical position, and the deposit on its surface is washed into boxes n' n'. The box n' will contain an impure schlich which must be again framed, whilst n' will probably contain a slime sufficiently enriched to be finished by the dolly tub.
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The slope of the rack table for washing tin stuff is \( \frac{7}{5} \) inches in 9 feet. The width is about 4 feet.

The average quantity of lead slime which can be washed per day of ten hours, is about 30 cwt., and the water necessary, say 600 gallons.

The general appearance of the rack is shown in the illustration, fig. 522. 1, table; 2, inclined plane upon which the stuff is lodged. Clean water flows over the ledge c. When the table 1 is turned in a vertical position, the racking girl washes it by depressing the lever e attached to the V-shaped launder n, thereby discharging the water which it may contain.

The heads, middles, and tails are lodged in the compartments x, o, and u, respectively.

The Machine Frame, fig. 523, consists of an inclined table, about 8 feet long, and 5 feet wide, with sides 5 inches high. At each end are fixed axles of iron, a n, which are centred in two vertical pieces of timber c d, and admit of the frame being turned perpendicularly. At the head of the frame is a ledge e, on which numerous lozenge-shaped pieces of wood are fixed in order to distribute the liquid stuff on the entire width of the frame.

From the frame head, the stuff falls on a sloping board r, which admits of being turned, as it is hung by leathern hinges, when the frame assumes an upright position. At one of the bottom corners of the frame is a box q, into which the chief part of the water from the table flows. In operating with this machine, the liquid matter is admitted to the frame head s, through the hole n, and flowing in a thin sheet on the table i, deposits the vein stuff according to its varying specific gravity, the best quality being heads from 1 to 2, the middles from 2 to 3, whilst the tails are lodged at the end of the apparatus. To the water wheel is attached a horizontal axle fitted at given distances with cams, which disengage at the proper time parts of the machinery connected with the frame. The first cam acts on
the rod \( k \), and stops the flow of tin stuff; the second cam disengages a catch beneath the displacing box \( e \), containing the frame water, and immediately the frame assumes a vertical position, striking in its movement a catch at \( m \), which upsets the V-shaped launder \( x \), containing pure water, in such a way as to wash the ore on the table into two cofers \( o \) and \( p \). The frame then returns to its horizontal position, and the orey matter is again admitted through \( h \). One boy can manage twenty of these frames. When employed in cleaning tin stuff, the two cofers \( o \) and \( p \) are discharged into separate pits about 15 feet long, 6 feet wide, and 12 or 15 inches deep. The refuse from the end of the frames, as well as the slimy water from the displacing box, is either thrown away or subjected to further treatment; the cover \( o \) is usually taken to the hand frames, after which it is tossed and packed, whilst the stuff from cover \( p \) is again submitted to machine framing.

*Hancock's Slide Frame.*—The ores and accompanying waste are brought into a state of suspension by water, and are then by adjustment made to pass over a slight fall, so as to produce the greatest regularity in its flow over tables fixed upon a given incline, each table having a sufficient drop from the table above. When the tables are sufficiently charged, clean water is introduced to pass over the charged table. The surfaces of the tables are
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subject to the action of brushes or brooms during a part or the whole time of both operations until the ores are sufficiently cleaned. In some cases the use of such brushes or brooms is dispensed with. The ores (on the tables) thus cleaned are washed off into cisterns by the action of water passing over the surfaces of the tables after they are raised to nearly perpendicular positions.

Fig. 524 represents, 1, framework to carry the gear on each side of the machine; 2, the stretcher or pivot piece on which all the tables are resting; 5, centre bearings of the tables, to which is attached an adjusting screw for raising or falling them; 4, a slide valve, which admits or shuts off, as required, the ores, which are previously brought into a thin consistency with water; 5, launder through which the ores pass to the heads, which are divided into sections and numbered; 6, the ores, &c., dropping from the heads into a launder, 7, the working edge of which is made level by an adjusting screw at each end for the ores to pass over; 8 is a stretcher, passing over the heads in both ends, bolted to 1, from which 6 and 7 are supported by three drop adjusting screws; 9 are four tables over which the ores have to pass, first receiving the deposit of the cleanest or best ores, and the rest in gradation; 10, the drop or fall from one table to another; 11, the balance cistern, into which the refuse from the table passes, and when full, by lifting the catch 12 it forms a balance for turning up the tables to be washed down, each table being connected with rods and lever 13; this done, such catch is lifted up, and 13 forms a returning balance for the tables; at 14 a stream of water is introduced, passing into 15 as a receiver; on the turning up of the tables, valves 16 are lifted by lever and rod 17, and admit the water into perforated launder 18 to wash off the ores into receivers 19, through which it passes out into deposit hutches. The slide valve 4 having admitted a sufficient quantity of ore, which has been deposited on the tables, is now closed, and the valve 20 is opened by the conductor’s hand at rod handle 21, through which a supply of water passes into launder 22, and flows over the tables for the purpose of cleaning the ores. The framework for the brushes 23 is carried on four wheels 24, each table being supplied with a brush 25, which brushes its respective tables upwards, and on arriving at the heads of the tables, the brushes being all connected, are lifted by lever, and 26 slips into the catch 27, and the brushes pass back over the tables without touching until the lever of the catch is struck out by 28, and the brushes drop again on the tables. Each brush is adjusted by screws and carried on arbors running across the frame. This frame with its appendages is propelled by a rod 29, attached to a beam 30, that can be worked by any sufficient power that may be applied.

The ores passing from the third and fourth tables through the two lower receivers 19 into a cistern, are lifted by a plunger n, attached to beam 30, by a rod 31, and passes back by launder 32 to be readmitted into slide valve 4, and repass the tables. In 11 balance cistern is a valve 33, which on the dropping of the table lets out the contents. 34 is a catch for holding the frame and brushes during the time of turning down and washing the tables. The catch is to be worked with or without brushes, as the character of the ores may require. It may be extended or diminished to any number of tables, and their size may vary as may be found necessary on the same principle. c is a wheel acting as a parallel motion for the plunger pole, and running on a bar of iron.

This machine was in constant use at the Great Polgooth Mine for some time, and, it is said, effected a saving of 30 per cent. in the dressing of slime ore. It is not so well adapted for rough as for the treatment of fine slimes; the apparatus may be managed by a boy at 8d. per day, and the cost of the machine complete is about £60.

Percussion Table, or Slosher, -The diagrams, figs. 525, 526, and 527, exhibit a plan, vertical section, and elevation of one of these tables, used in the Harz. The arbor, or great shaft, is shown in section perpendicularly to its axis, at A. The coms or wipers are shown round its circumference, one of them having just rested on n.
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These cams, by the revolution of the arbor, cause the alternating movements of a horizontal bar of wood, \( o, u \), which strikes at the point \( v \) against a table \( d, b, e, u \). This table is suspended by two chains \( t \), at its superior end, and by two rods at its lower end. After having been pushed by the piece, \( o, u \), it rebounds to strike against a block or bracket \( n \). A lever \( p, q \), serves to adjust the inclination of the movable table, the pivots \( q \) being points of suspension.

The stuff to be washed is placed in the chest \( a \), into which a current of water runs. The ore, floated upwards by the water, is carried through a sleeve on a small sloping table \( x \), under which is concealed the higher end of the movable table \( d, b, c, u \); and it thence falls on this table, diffusing itself uniformly over its surface. The particles deposited on this table form an oblong talus (slope) upon it; the successive percussions that it receives, determine the weightier matters, and consequently those richest in metal, to accumulate towards its upper end at \( u \).

Now the workman, by means of the lever \( p \), raises the lower end \( d \) a little in order to preserve the same degree of inclination to the surface on which the deposit is strewed. According as the substances are swept along by the water, he is careful to remove them from the middle of the table towards the top, by means of a wooden rake.

With this intent, he walks on the table \( d b c u \), where the sandy sediment has sufficient consistence to bear him. When the table is abundantly charged with the washed ore, the deposit is divided into three bands or segments, \( d b, b c, c u \). Each of these bands is removed separately and thrown into the particular heap assigned to it. Every one of these heaps thus formed becomes afterwards the object of a separate manipulation on a percussion table, but always according to the same procedure. It is sufficient in general to pass twice over this table the matters contained in the heap, proceeding from the superior band \( c u \), in order to obtain a pure \( \text{schlicht} \); but the heap proceeding from the intermediate belt \( b c \), requires always a greater number of manipulations, and the lower band \( d b \) still more. These successive manipulations are so associated that eventually each heap furnishes pure \( \text{schlicht} \), which is obtained from the superior band \( c u \). As to the lightest particles which the water sweeps away beyond the lower end of the percussion table, they fall into launders, whence they are removed to undergo a new manipulation.

Fig. 528 is a profile of a plan which has been advantageously substituted in the Harz, for that part of the preceding apparatus which causes the jolt of the piece \( o u \) against the table \( d b e u \). By means of this plan it is easy to vary, according to the circumstances of a manipulation always delicate, the force of percussion which a bar \( x y \) ought to communicate by its extremity \( y \). With this view a slender piece of wood \( u \) is made to slide in an upright piece \( v x \), adjusted upon an axis \( v \). To the piece \( u \) a rod of iron is connected, by means of a hinge \( z \); this rod is capable of entering more or less into a case or sheath in the middle of the piece \( v x \), and of being stopped at the proper point, by a thumb-screw which presses against this piece. If it be wished to increase the force of percussion, we must lower the point \( z \); if to diminish it, we must raise it. In the first case, the extremity of the piece \( u \) advances so much further under the cam of the driving shaft \( t \); in the second, it goes so much less forwards; thus the adjustment is produced.

The water for washing the ores is sometimes spread in slender streamlets, sometimes in a full body, so as to let two cubic feet escape per minute. The number of shocks communicated per minute, varies from 15 to 36; and the table may be pushed out of its settled position at one time three-quarters of an inch, at another nearly 8 inches. The coarse ore-sand requires in general less water, and less slope of table, than the fine and pasty sand.

The following remarks on the Freiberg shaking-table are by Mr. Upfield Green, of the Wildberg Mines, Prussia. The bed of the table is about fourteen feet long, by six feet wide, and is formed of double one-inch boards, fastened to a stout frame. The table is
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hung by four chains; the two hindermost are generally two feet long, with an inclination of 2 to 4 inches. The two front ones, which are attached to a roller for the purpose of altering the inclination of the table, are five feet six inches long, and hang perpendicularly when the table is at rest.

The table receives its action from cams inserted in the axle of a water-wheel, acting on the knee of a bent lever. The slimes, after being thoroughly stirred up by a tormentor, are conveyed by a launder in a box, where they are still further diluted with clean water, and passing through a sleeve with apertures corresponding to the size of the grain to be dressed, flow upon an inclined plane furnished with diffusing buttons, and from thence drip on to the shaking-table.

In treating rough slimes, the two hindermost chains are set at an inclination of 5 to 6 inches; and the table, with an inclination of 4 to 6 inches on its length, makes 36 to 32 pulsations of 5 to 6 inches in length per minute. About 24 cubic feet of diluted slimes, twelve of clean to one of slime water, enter the table per minute.

Before commencing the percussive action, the table is covered with a thin layer of rough slimes, and during the first few minutes only clean water is admitted. In consequence of the quantity of water and violent motion employed, the smaller and lighter particles of ore are likely to drift down the table, and a rake is therefore employed at intervals to recover such particles towards the head of the table. Care must, however, be taken not to allow the water to wear furrows in the deposit. From two to three hours are usually required for the roughest sand-slimes to deposit four to five inches on the head of the table. The crops are twice more passed over the shaking-table, and afterwards dollied. The rapidity of movement and quantity of clean water increase with each operation. The tails of the first operation, which are considerably poorer than the original stuff, may be either thrown away, or once more passed over the table, when the crop will be fit for treatment along with a fresh quantity of original slime. The treatment of fine slimes is similar to that of the rough, with the exception that the inclination of the table, quantity of slime-water, proportion of clean water, and length of stroke, constantly decrease with the degree of fineness of the slime; and the number of strokes increase in proportion. In fact, for the finest slimes, the table has no greater inclination than one inch on its whole length, while the stroke, of which 35 to 45 per minute are made, is no longer than \( \frac{3}{4} \) to \( \frac{1}{2} \) an inch. The time required for dressing varies with the nature of the slime operated on; five tons of rough slimes occupy sixty-eight hours, whilst the same quantity of very fine slimes requires no less than four times that period.

The Stossheerd.—To the kindness of Mr. Charles Remfry, of Stolberg, I am indebted for the elevation of a stossheerd erected at the Breinigerberg Mines, under his management. It has the merit of being extremely light, requiring little power, and of performing its work in a highly satisfactory manner. Fig. 529, a, table swung by chains, b, its width being

3 feet and length 12 feet. A greater or less inclination is given to the table by raising or lowering the screws c e'. At the upper end of the table is a buffer, n, which acts against a counter-buffer, r. A sliding bar, v, is also fitted between the table and percussion lever a. This lever is struck by cams fitted on the axis h, driven by the runner j. The slimes to be treated flow into the cistern k, 30 inches long, 13 inches wide, and 18 inches deep. Into this box a tormentor is introduced for the purpose of breaking up the slimes. The bottom is fitted with a launder, l, 7 inches long, and 3 inches wide. From this launder proceeds a head-board, m, expanded to the width of the table, and fitted with buttons, for the purpose of dispersing the slimes equally on the head of the table.

At the Breinigerberg Mines the slimes are very fine and tough, and not rich in metal. With the round buildle unimportant results were obtained; but the stossheerd concentrated
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them satisfactorily. About five tons of rough slime are enriched per day on four tables, whilst from nine to ten tons of the enriched slime are despatched in a similar period.

The four tables are managed by two boys, at a cost of 1s. 2d. per day. The cost of these machines complete, including water-wheel, 9 feet diameter, and 3 feet in breast, was £118.

Sleeping Tables.—Figs. 530, 531, represent a complete system of sleeping tables, tables dormientes, such as are mounted at Idria. Fig. 530 is the plan, and fig. 531 a vertical sec-

tion. The ores, reduced to a sand by stamps, pass into a series of conduits, a, b, c, which form three successive floors below the level of the floors of the works. The sand taken out of these conduits is thrown into the cells q, whence they are transferred into the trough i, and water is run upon them by turning two stop-cocks for each trough. The sand thus diffused upon each table, runs off with the water by a groove f, comes upon a sieve h, and spreads itself upon the board g, and thence falls into the slanting chest or sleeping table i k. The under surface k of this chest is pierced with holes, which may be stopped at pleasure with wooden plugs. There is a conduit m at the lower end of each table to catch the light particles carried off by the water out of the chest i k, through the holes properly opened, while the denser parts are deposited upon the bottom of the chest. A general conduit w passes across at the foot of all the chests, i k, and receives the refuse of the washing operations.

In certain mines of the Harz, tables called à balai, or sweeping tables, are employed. The whole of the process consists in letting flow, over the sloping table, in successive currents, water charged with the ore, which is deposited at a less or greater distance, as also pure water for the purpose of washing the deposited ore, afterwards carried off by means of this operation.

At the upper end of these sweeping tables, the matters for washing are agitated in a chest by a small wheel with vanes, or flap-boards. The conduit of the muddy waters opens above a little table or shelf; the conduit of pure water, which adjoins the preceding, opens below it. At the lower part of each of these tables there is a transverse slit, covered by a small door with hinges, opening outwardly, by falling back towards the foot of the table. The water spreading over the table, may at pleasure be let into this slit, by raising a bit of leather which is nailed to the table, so as to cover the small door when it is in the slit position; but when this is opened, the piece of leather then hangs down into it. Otherwise the water may be allowed to pass freely above the leather when the door is slit. The same thing may be done with a similar opening placed above the conduit. By means of these two slits, two distinct qualities of slitch may be obtained, which are deposited into two distinct conduits or canals. The refuse of the operation is turned into another conduit, and afterwards into ulterior reservoirs, whence it is lifted out to undergo a new washing.

Brunton's Machine.—This apparatus appears to be well adapted for the utilization of the ore contained in very fine slimes. At Devon Great Consols it is extensively employed, not
only to concentrate the viscous kind of slime sometimes found at the periphery of the round puddle, but also to dress the tops and middles resulting from the dollying operation.

The small water-wheel, shown in fig. 532, is sufficient to drive six of these machines, viz., three on each side. Before the stuff is permitted to enter upon the rotating cloth, it is disintegrated by tormentors, and passed through a sizing trommel; it then flows over the head or dispersing board \( I \), on to the cloth. This cloth rotates towards the stream on two axles, \( n \) and \( m \), and is supported by a third roller \( x \). It is also stiffened in its width by numerous laths of wood. Clean water is introduced behind the entrance of the slime, in order to give it the proper consistency. Different degrees of inclination are given to the cloth by raising or lowering the roller \( x \), by means of the screw \( k \). The heavier particles lodged on the cloth are caught in the wagon \( n \), whilst the lighter matter is floated over the roller \( x \). The following particulars are furnished by Captain Isaac Richards, of Devon Great Consols:

One revolution of the cloth is made in 4½ minutes; its length is about 294 feet, so that it travels say 6½ feet per minute. Its width is four feet two inches.

Before the slime comes upon the cloth it is reduced to a size of \( \frac{1}{100} \) of an inch, and yields an average of 11 of copper; but by means of this machine the stuff is concentrated so as to afford 5 per cent. In ten hours it will clean 1½ tons, at a cost of 1½ per ton. The speed of the cloth must, however, be varied with the condition of the stuff; if it be very poor, the cloth must travel very much slower, since the enrichment requires a longer period of time.

At the end of the machine, and worked by the same water-wheel, is a dolly tub; but the mode of working this apparatus is fully stated on the next page.

*Bradford's Slime Apparatus, fig. 532*, has been extensively employed at the Bristol Mines, situated in Connecticut, United States.

Its action is intended to imitate that of the vanning shovel. The slime enters by the launder \( A \), about 5 inches wide, and descends on the inclined head \( A' \), which expands from the width of the launder to within a few inches of the width of the table frame \( B \). The slime box \( A'' \) is perforated at \( p \) with numerous holes, each of which is fitted with small regulating pins.

The table \( n \) is 2 feet 2 inches wide, and 2 feet 10 inches long, with a bottom formed of copper gauze. It is suspended by the vertical rods \( K \) and \( k \), and varying degrees of inclination are given to the table by altering the levers \( H \). For the purpose of quickening or decreasing the action of the table, two cones are employed, \( L', L'' \), upon which the driving band is shifted as may be necessary. A band from a runner, fitted on the axis of the cone \( l \), communicates motion to a pulley-wheel, \( m \), upon the shaft of which are cranks attached to connecting rods \( g \), giving motion to the table.

When the machine is in operation, the ore flows over \( r \) into the launder beneath \( H \), whilst the waste is carried over the opposite end into the trough \( e \).

Prof. B. Silliman, Jr., and Mr. J. D. Whitney, give the following particulars of results realized by this machine:—The total weight of ore stuff pressed during 122 days was 11,948,000 pounds of rock stamped and crushed, or 5,080 tons miners' weight. The total ore sold from this quantity of stuff was 192 gross tons, (2,552 lbs.) or \( 2^{\frac{1}{100}} \) per cent. of the stuff worked over. By the Captain's vans the average richness of the stamp work (forming much the larger part of what goes to the separators) for 22 weeks was \( 2^{\frac{1}{2}} \) per cent. The humid assay of the average work from the stamps for five weeks in July and August, gave for the richness of the stuff dressed on the separators \( 3^{\frac{2}{2}} \) per cent. of ore, or \( 9^{5}\) per cent. of metallic copper. There is, therefore, an apparent loss in the tailings of \( 1^{\frac{1}{100}} \) per cent. of 30 per cent. ore, or \( 3^{\frac{1}{100}} \) of copper. The amount of
ores, however, lost in the tailings does not exceed \( \frac{5}{18} \) to \( \frac{7}{14} \) per cent., or about \( \frac{5}{123} \) per cent. of copper. The actual products of working, therefore, as may be seen, exceeded for the machines the average richness of the Captain's vans.

Of the total ore produced in this time, 181,126 pounds came from the separators, and 160,833 pounds from the jiggers. The whole amount of stuff, therefore, required to produce this amount of ore, estimated from the above ratio (1.15 : 1) is 768,680 pounds. This may be taken approximately as the actual quantity which passed over the separators, and if calculated on the Captain's vans, it should have produced 177,961 pounds of ore, while in fact it did produce 181,126 pounds, or a variation in excess for the machines of only 3,210 pounds. Each of the separators, therefore, dresses about 1\( \frac{1}{2} \) tons of rock daily, of stuff yielding an average of 2\( \frac{3}{5} \) per cent. of 30 per cent. ore.

**Dolly Tub or Packing-Keeve.**—This apparatus is employed for the purpose of excluding fine refuse from slime ore, which has been rendered nearly pure by previous mechanical treatment. In using it the workmen proceed thus:—The keeve, fig. 554, is filled to a certain height with water, and the dolly \( D \) introduced. A couple of men then take hold of the handle \( a \), and turning it rapidly cause the water to assume a circular motion. The tossing is then commenced by shovelling in the slime until the water is rendered somewhat thick. After continuing the stirring for a short period, the hoops \( e f \) are loosened, and the bar \( b \) with the dolly suddenly withdrawn. The tub is then packed by striking its outside with heavy wooden mallets. When this operation is terminated, the water is poured off through plug-holes in the side of the tub.

The object of the rotary motion created by the dolly is to scour off clayey or other matter adhering to the ore, whilst the packing hastens the subsidence of the denser portions. In one operation of this kind four distinct strata may be procured, as indicated by the lines \( a b, e d, e f, g h, c k \), in fig. 555.

The upper portion, viz. from \( a \) to \( n \), will probably have to be set aside for further washing, whilst the schlich \( c \) should be fit for market. The conical nucleus in the centre of the tub generally consists of coarse sand, and is usually further enriched on a copper bottom sieve, or else submitted to the action of a rye, or other suitable apparatus.

**Machine Dolly Tub.**—This keeve is packed by machinery represented in the accompanying
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woodcut, (fig. 536,) in which a is a small water-wheel working a vertical shaft n, and driving another o. At the bottom of this is fixed a notched wheel p, which presses outwardly thehammers s & x; these are mounted upon iron bars y & y', and violently driven upon the side of the keave by means of springs a o.

The degree to which ore can be concentrated by dollying must evidently depend upon several conditions:—1st. The initial percentage of the ore. 2d. The condition to which it is reduced. 3d. The matrix with which it is associated. 4th. The proportion of water employed. And lastly, if the rotation and packing have been judiciously performed. An experiment upon some sandschlich lead ore, much intermixed with fine carbonate of iron, gave the following results:—

<table>
<thead>
<tr>
<th>Description</th>
<th>Time Required</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduced into dolly tub, 17 cwt., assayed, 48%</td>
<td>-</td>
<td>6 minutes</td>
</tr>
<tr>
<td>Dolly rotated</td>
<td>-</td>
<td>5 &quot;</td>
</tr>
<tr>
<td>Dolly withdrawn</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tub packed</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Running off water</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skimming and cleaning out tub</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Top skimmings</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Second</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Clean ore, middles</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bottom</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fine schich</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

It may be remarked, that none of the various processes of dressing is more satisfactory than that of dollying, since, if carefully conducted, little or no loss of the total quantity of ore can occur.

JORDAN'S SYSTEM OF CONTINUOUS DRESSING.

We have now to notice a method of separating mineral sands of varying specific gravity, which was first used by Mr. T. B. Jordan at the Colonial Gold Works, in separating gold from quartz and other gangues with which it was associated. The plan was successfully practised for its original object during the years 1853 and 1854, and has since been elaborated for general application to dressing minerals.

The principle on which the system is founded, is the fact that bodies having the same bulk and various gravities, will fall through a column of water in the order of their densities, and hence that water moving upwards, at a rate greater than that at which any given body would descend through still water, will not allow such a body to descend through it, but will carry it up, and deliver it over the top of the containing vessel; therefore, granting that it is possible to reduce metallic ores to grains of uniform bulk, and taking the most simple case for our illustration, such as galeas and carbonate of lime, or quartz, it becomes at once obvious that an upward stream of water may be so regulated as to throw over all the lime or quartz, and allow all the galea to pass through it; but as we seldom find the associated material so simple, and as there is considerable difficulty in reducing minerals to grains of absolute identity of bulk, we must be content to complicate our machinery a little, and to put up with a somewhat less perfect or more laborious result than this argument seems to promise; nevertheless the author of this system contends, that the introduction of this element of washing by the up current, greatly facilitates the arrangement of dressing machinery of continuous action; and further, that if perfectly continuous action can be secured, so that each machine shall deliver its products to the next in succession which is to be employed on them, a very great improvement will have been effected, and a great saving made on the present cost of dressing; for it would not be difficult to show that nine-tenths of the labor consist of putting down, picking up, and transferring the material to the various processes through which it passes.

Our figure (537) must be taken as a diagram illustrative of Mr. Jordan's views. In actual practice, the construction is varied to meet the peculiarities of each case, while the general principle here illustrated is strictly adhered to. a is a tram bringing the rough material to the crushing rollers w; c c is a sort of rail wheel so arranged as not only to serve the usual purpose of returning the stuff not sufficiently crushed to the rollers, but also to separate that which is crushed into four or more sizes by the concentric rings of wire-work which divide the wheel into the compartments 6, 8, 10, 12. These numbers may be taken to denote the mesh in holes per lineal inch, and if so, all the materials from the crushing rolls being conveyed into the centre opening of the wheel will be sharply rolled over a six-hole sieve of
ores, dressing of.

great area; that part of it which is fine enough will pass through the mesh, that which is not will be carried up by the partition or bucket which returns it to the mill for further grinding. In the stuff which has passed the 6-hole sieve, and reached the compartment marked 6,

there will be a large proportion which will pass the next or 8-hole sieve, and again from the 8 to the 10 and 12, so that this wheel separates the ground stuff into four lots of approximately uniform grain. To secure the greatest effect from this separator, the stuff must be either perfectly dry, or ground with a good stream of water passing between the mills and through the wheel. Each compartment of the wheel is furnished with one stop-bucket and spout which, when it arrives at the top, delivers the contents of the compartment collected during the revolution into separate launders which carry it to as many different tubes, one of which is shown at b. These tubes are supplied with water from a main r, which is in connection with a reservoir some 12 or 14 feet above the level of the dressing floor; a few inches above the true bottom of the vessel b, there is a false bottom or diaphragm of wire-gauze, through which the water rises. Under the conditions described, the superintendent will have the power of regulating exactly the quantity of water which shall rise through each tube in a given time, and therefore the rate of the upward flow of the water; or, in other words, he will be able to adjust each stream as to throw over the waste, and allow the valuable part of each sand to fall on the wire bottom of its tube. It is of course admitted that the sizing effected in the wheel c, although better than by the usual methods, is still but an approximation to perfect sizing; and even if in the wheel it were perfect, still the rush through the launders would inevitably produce some dust ore if dry, or slime ore if wet, so that it would not do to throw away all that is washed over the top of the tubes; it therefore passes forward to the hutch r, where it falls on a fine gauze bottom sieve, parted longitudinally into as many divisions as there are tubes or sizes of sand to be worked; the bottom of each of these divisions is composed of a wire gauze, somewhat finer than that of the compartment of the parting wheel from which the sand came, and therefore none of the waste can find its way into the hutch; the action of this sieve is widely different from that of a jigging machine, inasmuch as the back and fore part of it have a different kind of motion, and it is a machine of continuous action, not requiring the constant attention of skilled labor. The crank e, by its constant rotation, dips the back of the sieve a few inches under water, and at the same time draws it back through the water at every revolution, and on rising and passing over the upper half of its revolution, it frees the sieve forward, while all its contents are above the surface of the water in the hutch. The front of the sieve is suspended by a pendulous rod from the point r, so that it has very little elevation and depression, while it has the same lateral motion as the back, and this enables the simple lauging scraper, which can move freely outwards but cannot pass inwards beyond the perpendicular, to throw over a portion of the waste at every stroke, this being much assisted by the stream constantly flowing over it. There are cleats placed across the bottom of these sieves both above and below, the tendency of which in giving direction to the waste, and stopping the rich slimes, will be readily understood on reference to the figure. The dolly tub k is
intended to meet the case of secondary products, such as "Jack," or other ore of zinc, frequently associated with lead. The peculiarities of its construction are such as are requisite to avoid the necessity for stopping and taking the machine apart in order to dig out its contents; it is accomplished partly by the direction given to the revolving arms which tend to lift the stuff, but principally by an up current of water of sufficient rate to throw over the lightest of the two materials now associated; as in the former case the original sizing is not abandoned, but a separate dolly tub is used for each size, so that the up current may still be adjusted to its work with the greatest precision; the step or bearing in the bottom of the tub is protected from the sand by a sheet-iron cone attached to the shaft, into which the clean water from the main is supplied, so that the stream of water constantly running from under the edges of this cone, keeps the step at all times perfectly clean and free from sand; \( r \) is the main for supplying to the tub, and there is a tap on the communicating pipe which regulates its force; \( m \) is the waste wagon, having a riddled bottom for drawing off the water; \( o \) is the "Jack" wagon into which the clean stuff from the tub is occasionally discharged by the sluice valve; and \( n \) is the lead wagon for carrying away the clean ore from the tubes; this wagon, like the others, is furnished with a ridded bottom covered with some material which is too fine in the mesh to allow any of the ore to pass; the ore is drawn off from the washing tubes from time to time in small quantities; each wagon remains under its own tube until it has received a full load, and is then wheeled off to the ore house; by this system, the inventor says, nothing is left to clean up but the hutch \( r \), and its sieve, which latter may require looking to two or three times a day, and the bottom of hutch about once in three days.

**Vanning** is a method commonly practised by the dressers of Cornwall and Devonshire, by which they ascertain approximately the richness and properties of the ore to be treated. If the object be to determine the value of a pile of stuff, it is carefully divided, then sampled, and a portion, say a couple of ounces, given to the vanner. If the stuff thus given should be rough, it is reduced to the tenure of fine sand, and in this state put upon the vanning shovel. The operator now resorts to a cistern or stream of water, and by frequently dipping the shovel into it, and imparting to the shovel when withdrawn a kind of irregular circular motion, he succeeds in getting rid of a greater or less portion of the waste; that which remains on the shovel is then considered equal to dressed work and assayed. So accurately is this operation performed by many of the timers, that parcels containing only fifteen pounds of tin ore per ton of stuff, are sold by it to the mutual satisfaction of both buyer and seller.

The vanning process is also well adapted for determining the properties of an ore. If, by this method, vein stuff should withstand concentration, no machinery is likely to dress it. If also the loss of ore is found great, then the apparatus to be employed for effecting the enrichment will have to be carefully considered and constructed.

**Fig. 538.** The vanning shovel \( a \) is 14 inches long, and 15 inches wide at the top, the edge of which is slightly turned up. The shovel is also formed with a hollow or depression. The handle is about 4 feet long. The vanning cistern is shown at \( n \).

**Hushing.—**It often occurs, that the water employed on the dressing floors makes its escape below the refuse or waste heaps. This may be used for the purpose of hushing, which operation is performed in the following manner.—The husher directs the escape water into a rivulet and introduces a given quantity of waste. He then builds a dam or reservoir, with a door or trap valve at the high end, in order to collect the necessary water for hushing, and puts aside all the large stones lying in the middle of the hush gutter in order to form them into a wall. After this, he starts his hush by lifting the door of the dam, which slides in a wooden frame adapted for that purpose.
ORES, DRESSING OF.

This allows the water to rush out, and displaces the waste to a certain depth, at the same time driving it forward.

If the bush has bored or uncovered a further quantity of large stones in the middle of the gutter, they are again removed to one side, since they would retard the force and action of the water. When these impediments are removed, the water is repeatedly discharged from the reservoir until the waste is flushed off the ore, which is found lying in holes, and around earth and fast stones, in the bed of the rivulet. A clay bottom is found to be most favorable for hushin, and the velocity and power of the stream should be proportioned to the size and density of the waste to be treated.

FORWARDING AND LIFTING APPARATUS.

Besides the machinery required for the enrichment of ores, it is a matter of great importance to introduce such auxiliary arrangements as shall not only facilitate actual dressing, but also be in themselves somewhat inexpensive. In this division, as in every other, the means should be strictly adapted to the end, and ought not to bear a cost disproportionate either to the circumstances or prospective advantages of an undertaking.

The shovel, fig. 539, usually employed in British mines, is of triangular shape, and made of good hammered iron pointed with steel. The dimensions vary, but one of an average size is about 11 inches wide at the top, and 35 inches from the point to the shank, weight 4 pounds, and costs one shilling; to which must be added, five pence for the hilt, or handle. The hilt should be of ash, free from knots and slightly curved.

Picking Boxes, fig. 540, are employed for the purpose of collecting the pebb and drudge ore from the stuff with which it may be mechanically intermixed. These boxes, or trays, are handled by children. They are made of deal, 1 inch thick, of the following dimensions: Length, 16 inches; depth, 7 inches; width at bottom, 7 inches; width at top, 10 inches; and cost about 1s. 3d. each. A ledge of wood to serve as a handle is sometimes nailed to the ends of the box.

Wheelbarrow.—The sides, ends, and bottom are composed of deal 1\frac{1}{2} inches thick. The ends are mortised to the sides, whilst the bottom is generally fastened by means of nails, and bound with slips of hoop iron at the angles. Hoop iron is also employed to protect the upper edges of the barrow. The wheel is often made of wrought iron, (\frac{1}{2} round,) and 14 inches diameter. Its axles rotate in wrought-iron cars. The extreme length of the sides of a well-proportioned barrow is 60 inches, depth at centre 9 inches; the ends are inclined, as shown in fig. 541. The cost of a barrow with wrought-iron wheels complete will vary from 6s. 6d. to 7s.

Handbarrow.—When large quantities of stuff have to be removed from place to place on the surface, and where it would be inconvenient to use the wheelbarrow, a barrow having handles at both ends is employed. It is made of deal planks 1\frac{1}{4} inches thick; the length of the sides is 5 feet 6 inches; depth in centre, 9 inches; width, 18 inches at top and 10 inches at bottom; length, 24 inches at top and 18 inches at bottom; cost complete, about 4s. 6d.

Railroads.—The gauge of surface roads varies from 2 feet 4 to 2 feet 6 inches within the rails. Instead of manufactured rails, common flat wrought-iron, 2\frac{1}{2} inches wide and \frac{1}{2} inch thick, is oftentimes employed. An extremely serviceable rail is formed of a strip of timber 2 inches square, upon which is laid wrought-iron, 1\frac{1}{2} inches wide and \frac{1}{4} inch thick, fastened by means of nails or screws.

Tram Wagon and Turn Table.—A good tram wagon and turn table are shown, fig. 543. The wagon is built of wrought-iron, with cast-iron wheels. The latter are usually 12 inches diameter, with flanges 1 inch deep and tires from 2 to 3 inches wide. The turn table is of cast-iron.
It does not rotate, but the wagon is easily directed to either line of rail by means of the circular ring; the elliptical loops in advance serving to guide and place the wheels on the rails.

Lifting Apparatus.—It sometimes happens that the surface is nearly level, and affords very little natural fall. In such case the enrichment of ores becomes more expensive from the necessity of shifting some of the various products by manual labor, and of introducing lifting appliances in order to procure the requisite elevations for carrying out the various elaborative processes. It is, moreover, scarcely practicable from the configuration of the ground to form useful reservoirs of water within a reasonable distance; neither does it commonly occur in such cases that a free supply can be obtained for washing.

The pumping engine is therefore required to furnish the requisite quantity of water. This is generally conveyed over the floors by wood launders, often interfering with each other and obstructing the direct circulation of carts, railways, &c. Now if a stand-pipe or pressure column were erected at the engine, and a main judiciously laid throughout the floors, it is obvious that it would not only remedy this evil, but also afford water for the several washing purposes, as well as motive power for common, dash, or other wheels, together with turbines, flap jacks, &c.

When an inconsiderable proportion of water has only to be raised to a higher level, the common shoe or chain-pump will be found to render effective service; but when a larger stream is requisite, it would be better to employ the rotary pump. This pump, fig. 544, has been brought to great perfection by Messrs. Gwynne; A is the suction-pipe, and B the discharge, the dotted lines showing the discharge B, horizontal when required.

Pumps of the following dimensions are stated to raise and discharge per minute for medium lifts, say from 10 to 70 feet high:—

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Stuff consisting of slimes and sand may be readily elevated by means of a Jacob's ladder or the Archimedean screw. For short elevations combined water and raff wheels devised by Mr. Charles Remfry of Stolberg, Prussia, may be advantageously employed.

Fig. 543, A, water-wheel; B, raff or inverted wheel; C, axis of both raff and water-wheels, carrying a tooth-driving wheel; D, sizing trommel; E, launder for inlet of stuff; F, discharge launder; G, shoot delivering water and raff to launder H; K, cistern receiving slime from trommel.

Slime Pits.—In the several operations of cleansing ores from mud, in grinding, and washing, where a stream of water is used, it is impossible to prevent some of the finely attenuated portions floating in the water from being carried off with it. Slime pits or
OXIDES.

The basins or reservoirs of these lakes are of various dimensions, and from 24 to 40 inches deep. Here the suspended ore is deposited, and nothing but clear water is allowed to escape.

The workmen employed in the mechanical preparation of the ores are paid, in Cumberland, by the piece, and not by day's wages. A certain quantity of crude ore is delivered to them, and their work is valued by the bing, a measure containing 14 cwt. of ore ready for smelting. The price varies according to the richness of the ore. Certain qualities are washed at the rate of 2s. 6d., or 3s. the bing; while others are worth at least 10s. The richness of the ore varies from 2 to 20 bings of galena per shift of ore; the shift corresponding to 8 wagon loads.

It is not essential to describe the dressing routine observable in any particular mine, since it is scarcely possible to observe the same system in any two distinct concerns. In the various modes of treatment, however, it may be remarked that the two leading features will always be reduction to a proper size and separation of the ore from the refuse. Until the vein stuff arrives at the cruser or stamps, the labor is chiefly one of picking and selecting, but from these machines usually commence a long series of divisions, subdivisions, selections, and rejections. To follow these out in their various ramifications would not only exceed the limits of this paper, but would perhaps be misunderstood by those not intimately acquainted with the subject.—J. D.

OTTO, OTTAR, or ATTAR OF ROSES. Otto of roses consists of two volatile oils; one solid and the other liquid at ordinary temperatures, in the proportion of about one of the former to two of the latter. To separate them, the otto must be frozen and compressed between folds of blotting paper, which absorb the liquid, and leave the solid oil. They may also be separated by alcohol, (of sp. gr. 0.8,) which dissolves the liquid and scarcely any of the solid oil. The solid oil, according to Sauzaure, contains only carbon and hydrogen, and these in equal number of atoms, and is therefore isomeric with oil of turpentine; it occurs in crystalline plates, fusible at 95° F. The liquid oil has not been carefully examined; it is uncertain whether it contains nitrogen, or only carbon, hydrogen, and oxygen.

Otto of roses is sometimes adulterated with some essential or fixed oils and spermacet. The purity of the otto is determined by the following test: put a drop or two of the oil to be tested in a watch-glass, and then add as many drops of concentrated sulphuric acid as of the oil; mix with a glass rod. All the oils are rendered more or less dark-colored by this process, while the otto of roses retains its purity of color; the oil of geranium if present acquires a strong disagreeable odor, which is very characteristic.—H. K. B.

OXIDES are compounds containing oxygen in definite proportions. They are usually divided into basic oxides, which unite with acids; acid oxides, which neutralize basic oxides, combining with them; and neutral oxides, which do not unite with either bases or acids. In addition to these are saline oxides, or compounds which are produced by the union of two oxides of the same metal.

OXIDES for polishing. Oxides of Iron.—The finest crocus and rouge are thus prepared. Crystals of sulphate of iron are taken from the pans in which they have crystallized, and are put at once into crucibles, or cast-iron pots, and exposed to a high temperature; the greatest care being taken to avoid the presence of dust. The least calcined portions are of a scarlet color, and form the jeweller's rouge for polishing gold or silver articles. The more calcined portions are of a purple or bluish purple color, and these form crocus for polishing brass or steel. It is found that the blue particles, which are those which have been exposed to the greatest heat, are the hardest. It will, of course, be understood that the result of the action of heat is to drive off the sulphuric acid from the protoside of iron, which becomes peroxidized in the process.

Lord Rosse, in the Philosophical Transactions, thus describes his process of preparing his polishing powder:

"I prepare the protoside of iron by precipitation with water of ammonia, from a pure dilute solution of sulphate of iron. The precipitate is washed, pressed in a screw-press till nearly dry, and exposed to a heat, which in the dark appears a dull low red. The only points of importance are, that the sulphate of iron should be pure—and the water of ammonia should be decidedly in excess, and that the heat should not exceed that I have described. The color will be a bright crimson, inclining to yellow. I have tried both potash and soda pure, instead of water of ammonia, but after washing with some degree of care, a trace of the alkali still remained, and the protoside was of an ochre color, and did not polish properly."

Jeweller's rouge is, however, frequently prepared in London by precipitating sulphate of iron with potash, well working the yellow oxide, and calcining it until it acquires a scarlet color.

Crocus is sometimes prepared after the manner recommended by Mr. Heath. Chloride of sodium and sulphate of iron are well mixed in a mortar; the mixture is then put into a shallow crucible and exposed to a red heat. Vapor escapes and the mass fuses. When no
more vapor escapes, remove the crucible and let it cool. The color of the oxide of iron produced, if the fire has been properly regulated, is a fine violet—if the heat has been too high, it becomes black. The mass when cold is to be powdered and washed, to separate the sulphate of soda. The powder of crocus is then to be submitted to a process of careful elutriation, and the finer particles reserved for the more delicate work.

**OXIDES OF IRON.** Four definite combinations of iron and oxygen are known namely:—

- **Peroxide**, FeO.
- **Peroxyde or sesquioxide**, FeO\(_2\).
- **Black or magnetic oxide**, FeO\(_2\)=FeO,Fe\(_{3}O_{4}\).
- **Ferric acid**, FeO\(_3\).

**Peroxide,** FeO.—Owing to the rapidity with which this oxide attracts oxygen from the atmosphere it is almost unknown in a separate state. When a solution of a salt of this oxide is mixed with a solution of caustic alkali, or ammonia, a bulky white precipitate is formed, which almost immediately begins to change color, becoming first green, then red brown, and when exposed freely to the air, as in the process of collecting and drying, it is entirely converted into the red brown sesquioxide.

It is a powerful base, neutralizing acids completely, forming salts which generally possess, when pure, a pale green color, and a nauseous styptic taste. This oxide is isomorphous with lime, magnesia, oxide of zinc, &c.

**Sesquioxide,** FeO\(_2\).—This oxide is known in several different forms. It is found native, beautifully crystalized, as *specular iron ore*, the finest specimens of which are brought from the Island of Elba; also as brown and red haematites, the former being a hydrate. Rust of iron is also a sesquioxide, containing variable quantities of peroxide.

It is prepared artificially, in the anhydrous state, by the ignition of ordinary sulphate of iron, or green vitriol, till no more acid fumes are given off, and is the residue left in the retorts in the manufacture of Nordhausen off of vitriol, (see SULPHURIC ACID.) After the ignition, it is reduced to powder and treated with water, when, after the coarser portions have subsided, the water is poured off, and allowed to stand for the finer portions to deposit. It is generally of a bright red color, but the color varies with the degree of heat to which it has been subjected. It is known in commerce under various names, as *coleather, trio, brown-red, rouge*, and *crocus martis*. That which has the brightest color is called *rouge*, and the brighter the color the more it is valued, if it is also fine. It is extensively used in the steel manufactures for giving a finished lustre to fine articles; it is also employed by silversmiths, under the name of plate powder and rouge; and by the opticians for polishing the specula of reflecting telescopes.

The hydrated oxide, prepared by precipitation with ammonia, is valuable in cases of poisoning by arsenic; for it is found to render the arsenic insoluble and therefore inert. For this purpose it should always be prepared by precipitating with ammonia, as it only requires about a quarter the quantity thus prepared to what would be required if precipitated by potash or soda. It has been found that twelve parts of the moist ammoniacal oxide are required for every part of arsenic to insure its full antidotal effects. Dr. A. Taylor says, that when the arsenic is in powder there is scarcely any effect produced; but, nevertheless, it has proved beneficial in most cases of arsenical poisoning, if given in time. The arsenious acid combines with the hydrated oxide and forms an insoluble subarsenite of iron, on the composition of which there are several opinions.

In the copper and alum works, a very large quantity of ochrey sediment is obtained; which is a sesquioxide of iron, containing a little sulphuric acid and alumina. This deposit, calcined in reverberatory hearths, becomes of a bright-red color, and when ground and elutriated, in the same way as described under *white lead*, forms a cheap pigment in very considerable demand in the French market, called *English red*.

An excellent powder for applying to razor-strops is made by igniting together in a crucible equal parts of well-dried green vitriol and common salt. The heat must be slowly raised and well regulated, otherwise the materials will boil over in a pasty state, and the product in a great measure be lost. When well made, out of contact of air, it has the brilliant aspect of plumbago. It has a satiny feel, and is a true *fier oleagine*, similar in composition to the Elba iron ore. It requires to be ground and elutriated; after which it affords, on drying, an impalpable powder, that may be either rubbed on a strop of smooth button leather, or mixed up with hog’s-lard or tallow into a stiff ercate.

An extremely fine rouge, which will not scratch the most delicate article, may be obtained by first precipitating the protocatele of iron from a solution of a protosalt of iron by oxalate of potash; this, when washed and dried, is gradually heated on a sheet of iron, when it is entirely converted into rouge, which, although not of a very bright color, is very fine.

The sesquioxide is a feeble base, isomorphous with alumina. The sesquioxide is a feeble base, isomorphous with alumina.

**Black or Magnetic Oxide,** FeO\(_2\)=FeO,Fe\(_{3}O_{4}\).—This oxide is also found native, as *magnetic iron ore*, which in the massive form is called *native lodestone*. It is found in Cornwall, Devonshire, Sweden, &c. This iron ore occurs in different forms, as earthy,
PAGING MACHINE.

OXYGEN. (Oxigen, Fr.; Sauerstoff, Germ.) is a permanent gas, and is best obtained by heating a mixture of chlorate of potash and binoxide of manganese, when the chlorate is decomposed into oxygen and chloride of potassium, KClO₃=KCl+O₂. Oxygen may be obtained from binoxide of manganese alone by the action of heat; but in this case, when used with chlorate of potash, the binoxide seems only to act in moderating the evolution of oxygen from the chlorate. When chlorate of potash alone is used the evolution of gas does not commence so soon, and often is given off rather suddenly at first, and may cause the fracture of the glass vessel.

Oxygen was first discovered by Dr. Priestley in England, and Scheele in Sweden, in 1774, about the same time, but independently of each other. Dr. Priestley called it diaphlogisticated air, and Scheele oxygened air. It was Lavoisier who gave it the name of oxygen, from the idea that it was the acidifying principle in all acids, (from οξύς, acid, and γεννάω, I beget, or give rise to;) but this name has of late years been shown to be a false one. Oxygen may be obtained from several substances, viz. by heating red oxide of mercury, HgO=Hg+O₂; by heating three parts of bichromate of potash with four parts of oil of vitriol in a glass retort. The products are sulphate of potash, sulphate of chromium, water, and oxygen —

\[
\text{KC}_3\text{O}_4\cdot\text{H}_2\text{O}+4\text{H}\text{SO}_4=\text{KSO}_4+\text{Cr}_2\text{SO}_4+\text{O}_2. 
\]

Oxygen is colorless, odorless, tasteless, incombustible, but the most powerful supporter of combustion. According to Regnault, 100 cubic inches of this gas weigh, at 60° F. and barometer at 30 inches, 34.19 grains, and its specific gravity is 1.4056. According to Berzelius and Dubong its sp. gr. is 1.0026.

Of all known substances oxygen is the most abundant in nature, for it constitutes at least three-fourths of the known terraneous globe. Water contains eight-ninths of its weight of oxygen; and the solid crust of our globe probably consists of at least one-third part by weight of this principle; for silica, carbonate of lime, and alumina,—the three most abundant constituents of the earth's strata,—contain each about one-half their weight of oxygen. Oxygen also constitutes about twenty per cent. by volume, or about twenty-three per cent. by weight, of the atmosphere; and it is an essential constituent of all living beings. Plants, in the sunlight, absorb carbonic acid, decompose it—keeping the carbon and liberating the oxygen; while animals, on the other hand, absorb oxygen and give off carbonic acid. Oxygen is the great supporter of combustion; substances which burn in air burn with greatly increased brilliancy in pure oxygen. Several propositions have been made to produce intense light by the use of pure oxygen gas, in the place of atmospheric air, as the active agent of combustion. The Drummond Light, the Bade Light, Fitzmaurice's Light, and others, employ oxygen in combination with carburetted hydrogen at the moment of entering into combustion; and some of these bring in the additional aid of a solid incombustible body, as lime, to increase the intensity of the illuminating power. The employment of any of these plans generally appears to depend upon the production of oxygen by some cheaper process than any at present employed.—H. K. B.

PAGING MACHINE. A self-setting machine for paging books and numbering documents, by Messrs. Waterlow and Sons, is of a very ingenious character. The numbering apparatus consists of five discs, which are provided with raised figures on their periphery, running from 1, 2, 3, &c. to 0; and these figures serve (like letter press type) to print the numbers required. The discs are mounted at the outer end of a vibrating frame or arm on
a common shaft, to which the first or units disc is permanently fixed; and the other four discs (viz. those for marking tens, hundreds, thousands, and tens of thousands) are mounted loosely thereon, so that they need not, of necessity, move when the shaft is rotating; but they are severally caused to move in the following order,—the tens disc performs one-tenth of a revolution for every revolution of the units disc; the hundreds disc makes one-tenth of a revolution of the tens disc; and so on. As the discs rise from the paper after every impression, the units disc is caused to perform one-tenth of a revolution (in order that the next number printed may be a unit greater than the preceding one) by a driving click taking into the teeth of a ratchet-wheel, fixed on the left-hand end of the shaft. The movement of the other discs is effected, at intervals, by means of a spring catch, affixed to the side of the units disc, and rotating therewith; which catch, each time that the units disc completes a revolution, is caused by a projection on the inner surface of the vibrating frame to project behind one of the raised figures on the tens disc, and carry it round one-tenth of a revolution on the next movement of the units disc taking place; and then, the catch having passed away from the projection, no further increase in the number imprinted by the tens disc will be effected until the units disc has performed another revolution. Every time that the tens disc completes a revolution, the spring catch causes the hundreds disc to move forward one-tenth of a revolution, and similar movements are imparted to the remaining discs at suitable times. The shaft is prevented from moving except when it is acted on by the driving click, by a spring detent, or pull entering the notches in the periphery of a wheel fixed on the right-hand end of the shaft; and the wheels or discs are held steady while numbering, and a clear and even impression of the figure is ensured. The leaves of the book to be paged or numbered are laid on the raised part of the table of the machine, covered with vulcanized india rubber, and as each page is numbered it is turned over by the attendant, so as to present a fresh page on their next descent. As the discs ascend after numbering each page, an inking apparatus (consisting of three rollers mounted in a swing frame, and revolving in contact with each other, so as to distribute the ink which is fed to the first roller evenly on to the third or inking roller) descends and inks the figures which are to be brought into action, when the numbering apparatus next descends. By this means books or documents may be paged or marked with consecutive numbers; for printing duplicate sets of numbers, as for bankers' books, a simple and ingenious contrivance is adopted. This consists in the employment of an additional ratchet-wheel, which is acted on by the driving click that moves the ratchet-wheel above mentioned, and is provided with a like number of teeth to that wheel. But the diameter of the additional ratchet-wheel is increased to admit of the teeth being so formed that the driving click will be thereby held back from contact with every alternate tooth of the first-mentioned ratchet-wheel; and thus the arrangement of the numbering discs will remain unchanged, to give, on their next descent, an duplicate impression of the number previously printed; but, on the re-ascending of the numbering apparatus, the click will act on a tooth of both ratchet-wheels, and move both forward one-tenth of a revolution; and, as the shaft accompanies the first ratchet-wheel in its movements, the number will consequently be changed.

Messrs. Schlesinger and Co. have introduced a paging machine, the capabilities of which are similar to the above, but somewhat differently obtained. The numbering discs in this instance are provided with ten teeth, with a raised figure on the end of each tooth; and they receive the change of motion from cog wheels mounted below them on the same frame. At each descent of the frame a stationary spring catch or hook piece drives round the wheel one tooth, that gears into the teeth of the units disc; and thereby causes the units disc to bring forward a fresh figure. The toothed wheels are somewhat narrower than the numbering discs, but one tooth of each wheel is enlarged laterally to about double the size of the other teeth; so that at the completion of every revolution of the wheel the projecting tooth shall act upon a tooth of the next disc, and carry that disc forward one-tenth of a revolution. By this means the requisite movements of the discs for effecting the regular progression of the numbers are produced; the first wheel driving its own disc, and communicating motion at intervals to the next disc, and the other wheels each receiving motion at intervals from the disc with which it is connected, and transmitting motion, at still greater intervals of time, to the next disc.

The machine is caused to print the figures in duplicate by drawing the spring catch out of action at every alternate descent of the frame, and thereby preventing any change of the figures taking place until after the next impression.

The numbers may be increased two units at each impression, so as to print all even or all odd numbers, by bringing a second catch into action, which causes the unit disc to advance one step during the ascending movement of the frame, in addition to the advance during the descent of the same.

PALISANDER WOOD, a name employed on the Continent for rosewood. Holzzapfel has the following remarks on this wood:—"There is considerable irregularity in the employment of the name of this wood among the French. Bergeron a kind of striped chinky is figured as bois de Pascal-viole, and stated as a wood brought by the Dutch from their South American colonies, and much esteemed."
PALLADIUM. Palladium is sometimes substituted for silver in the manufacture of mathematical instruments. The commoner metals may be plated with palladium by the electrotype process. Palladium is sometimes used in the construction of accurate balances, and for some of the works of chronometers. An alloy of palladium and silver is employed by the dentists from the circumstance that it does not tarnish. The influence of palladium in protecting silver from tarnishing is a remarkable and valuable property. The Wollaston medal given by the Geological Society is, in honor of its discoverer, made of palladium.

PALMITIC ACID. $\text{C}_6\text{H}_{12}\text{O}_4$. This acid was first discovered in palm oil, from which it derived its name; it has since been found in many other natural productions, and may also be manufactured artificially from some other substances. It is contained, for instance, in bees' wax, and that in considerable quantities; the proportion of the wax insoluble in boiling alcohol is called myricine, and is a palmitate of myricyle. This myricine requires a strong solution of potash to saponify it, and then the palmitic acid is obtained as palmitate of potash, from which it may be separated by adding an acid.

Spermaceti consists principally of a fat into which this acid enters, viz., a palmitate of cetyle. The palmitic acid may be obtained from this by dry distillation. It has also been proved to be contained in human fat.

It may be obtained artificially from different substances; one of which will be sufficient to mention here, viz., by fusing caustic potash with oleic acid, avoiding of course too high a temperature, and for this purpose a few drops of water are added from time to time to it.


$$\text{C}_6\text{H}_{12}\text{O}_4 + 2(\text{KO})_3 = \text{C}_6\text{H}_{12}\text{KO}_4 + 3\text{H}_2$$

The easiest and cheapest way of obtaining palmitic acid is by using palm oil. Palm oil, when fresh, consists principally of palmitin (palmitate of glycerine) and olein; but by the action of the air and moisture it speedily changes. The fats become decomposed into the fatty acids, (palmitic and oleic,) with the liberation of glycerine, which is itself afterwards converted into sebacie acid. The palm oil is first subjected to pressure to separate as much as possible the liquid portions; the solid residue is then boiled with an alkalil, and the soap thus formed decomposed by an acid; the palmitic acid, which thus separates, is then collected and purified by several crystallizations from alcohol.

None of these processes are employed commercially for obtaining palmitic acid, which is largely used in making candles. When thus required it is obtained in the same manner as stearic acid, by distilling with high-pressure steam. See CANDLES.

When pure, palmitic acid is a colorless solid substance, without smell, lighter than water but heavier than alcohol. It is insoluble in water, but freely soluble in boiling alcohol or ether. These solutions have an acid reaction, and when concentrated become almost solid on cooling; but if more dilute, the palmitic acid separates in groups of fine needles. It fuses at 143° Fahr., and becomes on cooling a mass of brilliant pearly scales. It may be distilled without decomposition, even without the presence of steam. It unites with bases to form salts, most of which are insoluble in water. It may also be made to unite with glycerine to form palmitin, in which state it previously existed in palm oil.

PALMITIN. As above stated, this is the principal constituent of fresh palm oil. It may be obtained from it by the following process:—The palm oil is subjected to pressure to remove the liquid portions, the solid portion is then boiled with alcohol, which dissolves the free fatty acids which may be present. The residue is then made palmitin, and it is purified by repeated crystallizations from ether. When thus obtained it is in small crystals; these fuse and become, on cooling, a semi-transparent mass, which may be easily reduced to powder. It is almost entirely insoluble in cold alcohol, and only slightly soluble in boiling alcohol, from which it again separates, on cooling, in flakes. It is soluble in all proportions in boiling ether.

PAPER, MANUFACTURE OF. The nature of some of the materials employed first claims attention. Silks, woollens, flax, hemp, and cotton, in all their varied forms, whether as cambric, lace, linen, holland, frostian, corduroy, bagging, canvas, or even as cables, are or can be used in the manufacture of paper of one kind or another. Still, rags, as of necessity they accumulate and are gathered up by those who make it their business to collect them, are very far from answering the purposes of paper making. Rags, to the paper-maker, are almost as various in point of quality or distinction, as the materials which are sought after through the influence of fashion. Thus the paper-maker, in buying rags, requires to know exactly of what the bulk is composed. If he is a manufacturer of white papers, no matter whether intended for writing or printing, silk, or woollen rags would be found altogether useless, inasmuch as it is well known the bleach will fail to act upon any animal substance whatever. And although he may purchase even a mixture in proper proportions, adapted for the quality he is in the habit of supplying, it is as essential in the processes of preparation that they shall previously be separated. Cotton in its raw state, as may be readily conceived, requires far less preparation than a strong hempen fabric, and thus, to meet the requirements of the paper-maker, rags are classed under different denominations, as for instance, besides "fines and seconds, there are "thirds" which are composed of
fustians, corduroy, and similar fabrics; stamps or prints, (as they are termed by the paper-maker,) which are colored rags, and also innumerable foreign rags, distinguished by certain well-known marks, indicating their various peculiarities. It might be mentioned, however, that although by far the greater portion of the materials employed in the manufacture of paper has already been alluded to, it is not from their possessing any exclusive suitableness—since various fibrous vegetable substances have frequently been used, and are indeed still successfully employed—but rather on account of their comparatively trifling value, arising from the limited use to which they are otherwise applicable.

To convey some idea of the number of substances which have been really tried—in the library of the British Museum may be seen a book printed in low Dutch, containing upwards of sixty specimens of paper, made of different materials, the result of one man's experiments alone, so far back as the year 1772. In fact, almost every species of tough fibrous vegetable, and even animal substance, has at one time or another been employed: even the roots of trees, their bark, the vine of hope, the tendrils of the vine, the stalks of the nettles, the common thistle, the stem of the hollyhock, the sugar cane, cabbage stalks, beet-root, wood shavings, sawdust, hay, straw, willow, and the like. Straw is occasionally used, in connection with other materials, such as linen or cotton rags, and even with considerable advantage, providing the processes of preparation are thoroughly understood. Where such is not the case, and the silken contained in the straw has not been destroyed, (by means of a strong alkali,) the paper will invariably be found more or less brittle; in some cases so much so as to be hardly applicable to any purpose whatever of writing utility. The waste, however, which the straw undergoes, in addition to a most expensive process of preparation, necessarily precludes its adoption to any great extent. Two inventions have been patented for manufacturing paper entirely from wood. One process consists in first boiling the wood in caustic soda lye in order to remove the resinous matter, and then washing to remove the alkali; the wood is next treated with chlorine gas or an oxygeneous compound of chlorine in a suitable apparatus, and washed to free it from the hydrochlorite acid formed: it is now treated with a small quantity of caustic soda, which converts it instantly into pulp, which has only to be washed and bleached, when it will merely require to be beaten for an hour or an hour and a half in the ordinary beating-engine, and made into paper. The other invention is very simple, consisting merely of a wooden box enclosing a grindstone, which has a roughened surface, and against which the blocks of wood are kept in close contact by a lever, a small stream of water being allowed to flow upon the stone as it turns, in order to free it of the pulp, and to assist in carrying it off through an outlet at the bottom. Of course the pulp thus produced cannot be employed for any but the coarsest kinds of paper. For writing and printing purposes, which manifestly are the most important, nothing has yet been discovered to lessen the value of rags, neither is it at all probable that there will, inasmuch as rags of necessity must continue accumulating; and before it will answer the purpose of the paper-maker to employ new material, which is not so well adapted for his purpose as the old, he must be enabled to purchase it for considerably less than it would be worth in the manufacture of textile fabrics; and besides all this rags possess in themselves the very great advantage of having been repeatedly prepared for paper-making by the numerous alkaline washings which they necessarily receive during their period of use.

With all the drawbacks attending the preparation of straw there is certainly no fibre to compete with it at present as an auxiliary to that of rags. A thick brown paper, of tolerable strength, may be made from it cheaply, but for printing or writing purposes only an inferior description can be produced, and of little comparative strength to that of rag paper. Its chief and best use is that of imparting stiffness to common newspaper. Some manufacturers prefer for this purpose an intermixture of straw with paper shavings, and others in place of the paper shavings give the preference to rags. The proportion of straw used in connection with rags or paper shavings varies from 50 to 80 per cent.

The cost at the present time of producing two papers of equal quality, one entirely from straw, and the other entirely from rags, would be very nearly equal; for although the cost of the rags would be at least £17 per ton, and the cost of the straw not more than £2 per ton, in addition to the greatly increased cost of preparing the straw, the rags would only waste one-third, while the straw would waste fully one-half. Thus taking into consideration the waste which each undergoes in process of preparation, the actual cost of material in producing a ton of paper may be stated relatively as £25 for rags, and £4 for straw. The cost, however, of preparation, which includes power, labor, and chemicals, being so very much greater in the case of the straw,—from two to three times as much as that of rags—a similarity of value is thus ultimately attained.

In order to reduce the straw to a suitable consistency for paper-making, it is placed in a boiler, with a large quantity of strong alkali, and with a pressure of steam equal to 120 and sometimes to 150 lbs. per square inch; the extreme heat being attained in super-heating the steam after it leaves the boiler, by passing it through a coiled pipe over a fire, and then the water being distilled and the straw softened to pulp, which, after being freed from the alkali by washing it in cold water, is subsequently bleached and beaten in the ordinary rag engine, to which we shall presently refer.
The annual consumption of rags in this country alone far exceeds 120,000 tons, three-fourths of which are imported, Italy and Germany furnishing the principal supplies. That the condition in which the rags are imported furnishes any criterion of the national habits of the people from which they came, as has been frequently asserted, however plausible in theory, must at least be received with caution.

All that can be said as to the suitableness of fibre in general, may be summed up in very few words; any vegetable fibre having a corrugated edge, which will enable it to cohere in the mass, is fit for the purpose of paper-making; the extent to which such might be applied can solely be determined by the question of cost in its production; and hitherto every thing which has been proposed as a substitute for rags has been excluded either by the cost of freight, the cost of preparation, or the expenses combined.

In considering the various processes or stages of the manufacture of paper, we have first to notice that of carefully sorting and cutting the rags into small pieces, which is done by women; each woman standing at a table frame, the upper surface of which consists of very coarse wire cloth; a large knife being fixed in the centre of the table, nearly in a vertical position. The woman stands so as to have the back of the blade opposite to her, while at her right hand on the floor is a large wooden box, with several divisions. Her business consists in examining the rags, opening the seams, removing dirt, pins, needles, and buttons of endless variety, which would be liable to injure the machinery, or damage the quality of the paper. She then cuts the rags into small pieces, not exceeding 4 inches square, by drawing them sharply across the edge of the knife, at the same time keeping each quality distinct in the several divisions of the box placed on her right hand. During this process, much of the dirt, said, and so forth, passes through the wire cloth into a drawer underneath, which is occasionally cleaned out. After this, the rags are removed to what is called the dusting machine, which is a large cylindrical frame covered with similar coarse iron wire-cloth, and having a powerful revolving shaft extending through the interior, with a number of spokes fixed transversely, nearly long enough to touch the cage. By means of this contrivance, the machine being fixed upon an incline of some inches to the foot, the rags, which have been put in at the top, have any remaining particles of dust that may still adhere to them effectually beaten out by the time they reach the bottom.

The rags being thus far cleansed, have next to be boiled in an alkaline lye or solution, made more or less strong as the rags are more or less colored, the object being to get rid of the remaining dirt and some of the coloring matter. The proportion is from four to ten pounds of carbonate of soda with one-third of quick lime to the hundred weight of material. In this the rags are boiled for several hours, according to their quality.

The method generally adopted is that of placing the rags in large cylinders, which are constantly, though slowly, revolving, thus causing the rags to be as frequently turned over, and into which a jet of steam is cast with a pressure of something near 30 lbs. to the square inch.

After this process of cleansing, the rags are considered in a fit state to be torn or macerated until they become reduced to pulp, which was accomplished, some five and thirty or forty years since, by setting them to heat and ferment for many days in close vessels, whereby in reality they underwent a species of putrefaction. Another method subsequently employed was that of beating them by means of stamping-rods, shod with iron, working in strong oak or stone mortars, and moved by water-wheel machinery. So rude and ineffective however was this apparatus, that no fewer than forty pairs of stamps were required to operate a night and a day in preparing one hundred weight of material. At the present time, the average weekly consumption of rags, at many paper mills, exceeds even 30 tons. The cylinder or engine mode of comminuting rags into paper pulp appears to have been invented in Holland, about the middle of the last century, but received very little attention here for some years afterwards. The accompanying drawing will serve to convey some idea of the wonderful rapidity with which the work is at present accomplished. No less than twelve tons per week can now be prepared by means of this simple contrivance. The horizontal section represents an oblong cistern, of cast-iron, or wood lined with lead, into which the rags, with a sufficient quantity of water, are received. It is divided by a partition, as shown (a), to regulate the course of the stuffing; the spindle upon which each cylinder c moves, extending across the engine, and being put in motion by a band wheel or pinion at the point n. One cylinder is made to traverse at a much swifter rate than the other, in order that the rags may be the more effectually triturated. The cylinders c, as shown in the vertical section, are furnished with numerous cutters, running parallel to the axis, and again beneath them similar cutters are mounted (o) somewhat obliquely, against which, when in motion, the rags are drawn by the rapid rotation of the cylinders, and thus reduced to the smallest filaments requisite, sometimes not exceeding the sixteenth of an inch in length; the distance between the fixed and movable blades being capable of any adjustments, simply by elevating or depressing the bearings upon which the necks of the shaft are supported. When in operation, it is of course necessary to enclose the cylinders in a case, as shown, k; otherwise, a large proportion of the rags would, inevitably, be thrown
out of the engine. The rags are first worked coarsely, with a stream of water running through the engine, which tends effectually to wash them, as also to open their fibres; and in order to carry off the dirty water, what is termed a washing drum is frequently employed, consisting simply of a framework covered with very fine wire gauze, in the interior of which, connected with the shaft or spindle, which is hollow, are two suction tubes, and by this means, on the principle of a siphon, the dirty water constantly flows away through a larger tube running down outside, which is connected with that in the centre, without carrying away any of the fibre.

After this, the mass is placed in another engine, where, if necessary, it is bleached by an admixture of chloride of lime, which is retained in the engine until its action becomes apparent. The pulp is then let down into large slate cisterns to steep, prior to being reduced to a suitable consistency by the beating engine, as already described. The rolls or cylinders, however, of the beating engine are always made to rotate much faster than when employed in washing or bleaching, revolving probably from 120 to 150 times per minute; and thus, supposing the cylinders to contain 48 teeth each, passing over eight others, as shown in the drawing, effecting no fewer than 103,680 cuts in that short period. From this the great advantage of the modern engine over the old-fashioned mortar machine, in turning out a quantity of paper pulp, will be at once apparent. The introduction of coloring matter in connection with the paper manufacture is accomplished simply by its inter-mixture with the pulp while in process of beating in the engine.

Although the practice of bluing paper is not, perhaps, so customary now as was the case a few years back, the extent to which it is still carried may be a matter of considerable astonishment. On its first introduction, when, as regards color, the best paper was any thing but pleasing, so striking a novelty would not doubt be hailed as a great improvement, and as such received into general use; but the superior delicacy of a first class paper now made without any coloring matter whatever, and without any superfluous marks on its surface, is so truly beautiful both in texture and appearance, as to occasion some surprise that it is not more generally used.*

Common materials are frequently and very readily employed, through the assistance of coloring matter, which tends to conceal the imperfection. Indeed it would be difficult to name an instance of apparent deception more forcible than that which is accomplished by the use of ultramarine. Until very recently the fine bluish tinge given to many writing papers was derived from the admixture of that formerly expensive, but now, being prepared artificially, cheap, mineral blue, (see Ultramarine,) the oxide of cobalt, generally termed

* See Richard Herring's "Pure Wove Writing Paper."
smalts, which has still the advantage over the ultramarine of imparting a color which will endure for a much longer period. 1 pound of ultramarine, however, going further than 4 of smalts, the former necessarily meets with more extended application, and where the using is rightly understood, and the materials employed instead of being fine rags, comparative rubbish, excessively bleached, its application proves remarkably serviceable to the paper-maker in concealing for a time all other irregularities, and even surpassing in appearance the best papers of the kind.

At first the introduction of ultramarine led to some difficulty in sizing the paper, for so long as smalts continued to be used, any amount of alum might be employed, and it was actually added to the size to preserve it from putrefaction. But since artificial ultramarine is bleached by alum, it became of course necessary to add this salt to the size in very small proportions, and as a natural consequence the gelatine was no longer protected from the action of the air, which led to incipient decomposition; and in such cases the putrefaction, once commenced, proceeded even after the size was dried on the paper, and gave to it a most offensive smell, which rendered the paper unsaleable. This difficulty, however, has now been overcome, and providing the size be quite free from taint when applied to the paper, and quickly dried, it will not subsequently occur; but if decay has once commenced, it cannot be arrested by drying only.

The operation of paper-making, after the rags or materials to be used have been thus reduced and prepared, may be divided into two kinds: that which is carried on in hand-mills, where the formation of the sheet is performed by manual labor; and that which is carried on in machine-mills, where the paper is produced upon the machine wire-cloth in one continuous web.

With respect to hand-made papers, the sheet is formed by the vatman’s dipping a mould of fine wire cloth fixed upon a wooden frame, and having what is termed a deckle, to determine the size of the sheet, into a quantity of pulp which has been previously mixed with water to a requisite consistency; when, after gently shaking it to and fro in a horizontal position, the sheet becomes so connected as to form one uniform fabric, while the water drains away. The deckle is then removed from the mould, and the sheet of paper turned off upon a felt, in a pile with many others, a felt intervening between each sheet, and the whole subjected to great pressure, in order to displace the superfluous water; when, after being dried and pressed without the felts, the sheets are dipped into a tub of fine animal size, the superfluity of which is again forced out by another pressing; each sheet, after being finally dried, undergoing careful examination before it is finished.

Thus we have, first, what is termed the water-leaf, the condition in which the paper appears after being pressed between the felts—this is the first stage. Next, a sheet from the bulk, as pressed without the felts, which still remains in a state unfit for writing on, not having been sized. Then a sheet after sizing, which completely changes its character; and lastly one with the finished surface. This is produced by placing the sheets separately between very smooth copper plates, and then passing them through rollers, which impart a pressure from 20 to 50 tons. After only three or four such pressings, it is simply called roller, but if passed through more frequently, the paper acquires a higher surface, and is then called glazed.

The paper-making machine is constructed to imitate in a great measure, and in some respects to improve, the processes used in making paper by hand; but its chief advantages are the increased rapidity with which it accomplishes the manufacture, and the means of producing paper of any size which can practically be required.

By the agency of this admirable contrivance, which is so adjusted as to produce the intended effect with unerring precision, a process which, in the old system of paper-making, occupied about three weeks, is now performed in as many minutes.

The paper-making machine is supplied from the “chest” or reservoir \( R \), into which the pulp descends from the beating engine, when sufficiently ground; being kept in constant motion, as it descends, by means of the agitator \( G \), in order that it shall not settle. From this reservoir the pulp is again conveyed by a pipe into what is technically termed the “lifter” \( L \), which consists of a cast-iron wheel, enclosed in a wooden case, and having a number of buckets affixed to its circumference. The trough \( T \), placed immediately beneath the endless wire \( W \), is for the purpose of receiving the water which drains away from the pulp during the process of manufacture; and as this water is frequently impregnated with certain chemicals used in connection with paper-making, it is returned again by a conducting spout into the “lifter,” where, by the rotation of the buckets, both the pulp and back-water become again thoroughly mixed, and are together raised by the lifter through the spout \( T \), into the trough \( W \), where the pulp is strained by means of a sieve or “knotter,” as it is called, which is usually formed of brass, having fine slips cut in it to allow the comminuted pulp to pass through, while it retains all lumps and knots; and so fine are these openings, in order to free the pulp entirely from any thing which would be liable to damage the quality of the paper, that it becomes necessary to apply a means of exhaustion underneath, in order to facilitate the passage of the pulp through the strainer.
The lumps collected upon the top of this knotter, more particularly when printing papers are being manufactured, are composed, to a considerable extent, of india-rubber, which is a source of much greater annoyance to the paper-maker than is readily conceived. For, in the first place, it is next to impossible in sorting and cutting the rags to free them entirely from the braiding, and so forth, with which ladies adorn their dresses; and in the next, the bleach failing to act upon a substance of that character, the quality of the paper becomes greatly deteriorated, by the large black specks which it occasions, and which, by the combined heat and pressure of the rolls and cylinders, enlarge considerably as it proceeds.

Passing from the strainer, the pulp is next made to distribute itself equally throughout the entire width of the machine, and is afterwards allowed to flow over a small lip or ledge, in a regular and even stream, whence it is received by the upper surface of the endless wire \( k \), upon which the first process of manufacture takes place. Of course the thickness of the paper depends in some measure upon the speed at which the machine is made to travel; but it is mainly determined by the quantity of pulp allowed to flow upon the wire, which by various contrivances can be regulated to great nicety. Paper may be made by this machine, considerably less than the thousandth of an inch in thickness, and although so thin, it is capable of being colored, it is capable of being glazed, it is capable of receiving a water-mark; and what is perhaps still more astonishing, a strip not exceeding 4 inches in width, is sometimes capable of sustaining a weight of 20 lbs., so great is its tenacity.

But, to return to the machine itself. The quantity of pulp required to flow from the vat \( n \) being determined, it is first received by the continuous woven wire \( x \), upon which it forms itself into paper; this wire gauze, which resembles a jack-towel, passing over the small copper rollers \( r \), round the larger one marked \( o \), and being kept in proper tension by two others placed underneath. A gentle vibratory motion from side to side is given to the wire, which assists to spread the pulp evenly, and also to facilitate the separation of the water, and by this means, aided by a suction pump, the pulp solidifies as it advances. The two black squares on either side of the “dandy” roller \( r \) indicate the position of two wooden boxes, from which the air is partially exhausted, thus causing the atmospheric pressure to operate in compri

ing the pulp into paper, the water and moisture being drawn through the wire and the pulp retained on the surface.

Next, we have to notice the deckle or boundary strips \( q \), which regulate the width of the paper, travelling at the same rate as the wire, and thus limiting the spread of the pulp. The “dandy” roller \( r \) is employed to give any impression to the paper that may be required. We may suppose, for instance, that the circumference of that roller answers exactly to the length or breadth of the wire forming a hand mould, which, supposing such wire to be fixed or curved in that form, would necessarily leave the same impression as when employed in the ordinary way. Being placed between the air boxes, the paper becomes impressed by it when in a half-formed state, and whatever marks are thus made, the paper will effectually retain. The two rollers following the dandy, marked \( k \) and \( o \), are termed couching rollers, from their performing a similar operation in the manufacture of machine-made papers to the business of the coucher in conducting the process by hand. They are simply wooden rollers covered with felt. In some instances, however, the upper couch roll \( n \) is made to answer a double purpose. In making writing or other papers where salts, ultramarine, and various colors are used,
considerable difference will frequently be found in the tint of the paper when the two sides are compared, in consequence of the coloring matter sinking to the lower side, by the natural subsidence of the water, or from the action of the suction boxes; and to obviate this, instead of employing the ordinary couch roll, which acts upon the upper surface of the paper, a hollow one is substituted, having a suction box within it, acted upon by an air pump, which tends in some measure to counteract the effect, justly considered objectionable. Merging from those rollers the paper is received from the wire gauze by a continuous felt, which conducts it through two pair of pressing rollers, and afterwards to the drying cylinders. After passing through the first pair of rollers the paper is carried along the felt for some distance, and then turned over, in order to receive a corresponding pressure on the other side, thus obviating the inequality of surface which would otherwise be apparent, especially if the paper were to be employed for books.

The advantage gained by the use of so great a length of felt, is simply that it becomes less necessary to stop the machine for the purpose of washing it, than would be the case if the felt were limited in length to its absolute necessity.

In some instances, when the paper being made is sized in the pulp, with such an ingredient as rosin, the felt becomes so completely clogged in the space of a few hours, that unless a very great and apparently unnecessary length of felt be employed, a considerable waste of time is constantly incurred in washing or changing the felt.

The operation of the manufacture will now be apparent. The pulp flowing from the reservoir into the filter, and thence through the strainer, passes over a small lip to the continuous wire, being there partially compacted by the shaking motion, more thoroughly so on its passage over the air boxes, receiving any desired marks by means of the dandy roller passing over the continuous felt between the first pressing rollers, then turned over to receive a corresponding pressure on the other side, and from thence off to the drying cylinders, which are heated more or less by injected steam; the cylinder which receives the paper first, being heated less than the second, the second than the third, and so on; the paper after passing over those cylinders, being finally wound upon a reel, as shown, unless it be printing paper, which can be sized sufficiently in the pulp, by an admixture of alum, soda, and resin, or the like; in which case it may be at once conducted to the cutting machine, to be divided into any length and width required. But, supposing it to be intended for writing purposes, it has first to undergo a more effectual method of sizing, as shown in the accompanying drawing; the size in this instance being made from parings obtained from tanners, curriers, and parchment-makers, as employed in the case of hand-made papers. Of course, sizing in the pulp or in the engine offers many advantages; but as gelatine, or animal size, which is really essential for all good writing qualities, cannot at present be employed during the process of manufacturing by the machine without injury to the felts, it becomes necessary to pass the web of paper, after it has been dried by the cylinders, through this apparatus.

In most cases, however, the paper is at once guided as it issues from the machine, through the tub of size, and is thence carried over the skeleton drums shown, inside each of which are a number of fans rapidly revolving; sometimes there are forty or fifty of these drums in succession, the whole confined in a chamber heated by steam. A paper-machine with the sizing apparatus attached, sometimes measures, from the wire-cloth where the pulp first flows on, to the cutting machine at the extremity, no less than one thousand feet. The advantage of drying the paper in this manner over so many of these drums is, that it turns out much harder and stronger, than if dried more rapidly over heated cylinders. Some manufacturers adopt a peculiar process of sizing, which in fact answers very much better, and is alike applicable to papers made by hand or by machine, provided the latter description be first cut into pieces or sheets of the required dimensions. The contrivance consists of two revolving felts, between which the sheets are carried under several rollers through a long trough of size, being afterwards hung up to dry upon lines, previously to
rolling or glazing. The paper thus sized becomes much harder and stronger, by reasons of the freedom with which the sheets can contract in drying; and this is mainly the reason why paper made by hand continues to be so much tougher than that made by the machine, in consequence of the natural tendency of the pulp to contract in drying, and consequently becoming, where no resistance is offered, more curved or entangled, which of course adds very considerably to the strength and durability of the paper. In making by the machine, this tendency is completely checked.

It may be interesting to mention, that the first experiment for drying paper by means of heated cylinders was made at Gellibrand's calico printing factory, near Stepney; a reel of paper, in a moist state, having been conveyed there from Dartford, in a post chaise. The experiment was tried in the presence of the patentees of the paper machine and Mr. Donkin, the engineer, and proved highly satisfactory, and the adoption of copper cylinders, heated by steam, was thenceforth considered indispensable.

The next operation to be noticed, now that the paper is finished, is that of cutting it into standard sizes. Originally, the reel upon which it was finally wound, was formed so that its diameter might be lessened or increased at pleasure, according to the sizes which were required. Thus, for instance, supposing the web of the paper was required to be cut into sheets of 18 inches in length, the diameter of the reel would be lessened to 6 inches, and thus the circumference to 18 inches; or if convenient it would be increased to 36 inches, the paper being afterwards cut into two by hand with a large knife, the width of the web being regulated by the deckle straps, to either twice or three times the width of the sheet, as the case might be. However, in regard to the length, considerable waste, of necessity, arose, from the great increase in the circumference of the reel as the paper was wound upon it, and to remedy this, several contrivances have been invented. To dwell upon their various peculiarities or separate stages of improvement, would prove of little comparative interest to the general reader; it will, therefore, be well to limit attention to the cutting machine, of which an illustration is given, which is unquestionably the best, as well as the most ingenious, invention of the kind.

The first movement or operation peculiar to this machine is that of cutting the web of paper longitudinally, into such widths as may be required; and this is effected by means of circular blades, placed at stated distances, which receive the paper as it issues direct from the other machinery, and by a very swift motion, much greater than that at which the paper travels, slit it up with unerring precision wherever they may be fixed.

A pair of those circular blades is shown in the drawing A, the upper one being much larger than the lower, which is essential to the smoothness of the cut. And not only is the upper blade larger in circumference, but it is also made to revolve with much greater rapidity, by means of employing a small pinion, worked by one at least twice its diameter, which is fixed upon the same shaft as the lower blade, to which the motive power is applied. The action aimed at is precisely such as we obtain from a pair of scissors.

The web, as it is termed by the paper-maker, being thus severed longitudinally, the next operation is that of cutting it off into sheets of some particular length horizontally; and to do this requires a most ingenious movement. To give a very general idea of the contrivance, the dotted line represents the paper travelling on with a rapidity in some cases of
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80 feet per minute, and yet its course has to be temporarily arrested while the required separation is effected, and that too without the paper's accumulating in any mass, or getting creased in the slightest degree.

The large drum, over which the paper passes, in the direction indicated by the arrows, has simply an alternating motion, which serves to gather the paper in such lengths as may be required; the crank arm c, which is capable of any adjustment either at top or bottom, regulating the extent of the movement backwards and forwards, and thus the length of the sheet. As soon as the paper to be cut off has passed below the point p, at which a presser is suspended, having an alternating motion given to it, in order to make it approach to and recede from a stationary presser board, it is taken hold of as it descends from the drum, and the length pendent from the presser, is instantly cut off by the movable knife k to which motion is given by the crank r, the connecting rod o, the lever n, and the connecting rod l. The combined motion of these rods and levers admits of the movable knife k, remaining nearly quiescent for a given time, and then speedily closing upon the fixed knife l, cutting off the paper in a similar manner to a pair of shears, when it immediately slides down a board, or in some instances is carried along a revolving felt, at the extremity of which several men or boys are placed to receive the sheets, according to the number into which the width of the web is divided.

As soon as the pressers are closed for a length of paper to be cut off, the motion of the gathering drum is reversed, removing out the paper upon its surface, which is now held between the pressers; the tension rod l, taking up the slack in the paper as it accumulates, or rather bearing it gently down, until the movement of the drum is again reversed to furnish another length. The handle u is employed merely to stop a portion of the machinery, should the water-mark not fall exactly in the centre of the sheet, when by this means it can be momentarily adjusted.

The paper being thus made, and cut up into sheets of stated dimensions, is next looked over and counted out into quires of 24 sheets, and afterwards into reams of 20 quires; which subsequently are carefully weighed, previously to their being sent into the market.

Connected with the manufacture of paper, there is one point of considerable interest and importance, and that is, what is commonly, but erroneously, termed the water-mark, which may be noticed in the Times newspaper, in the Bank of England Notes, Cheques, and Bills, as also in every Posting and Receipt Label of the present day.

The curious, and in some instances absurd terms, which now puzzle us so much in describing the different sorts and sizes of paper, may frequently be explained by reference to the various paper marks which have been adopted at different periods. In ancient times, when comparatively few people could read, pictures of every kind were much in use where writing would now be employed. Every shop, for instance, had its sign, as well as every public-house, and those signs were not then, as they often are now, only painted upon a board, but were invariably actual models of the thing which the sign expressed—as we still occasionally see some such sign as a bee-hive, a tea-canister, or a doll, and the like. For the same reason printers employed some device, which they put upon the title-pages and at the end of their books, and paper-makers also introduced marks, by way of distinguishing the paper of their manufacture from that of others; which marks becoming common, naturally gave their names to different sorts of paper. And since names often remain long after the origin of them is forgotten and circumstances are changed, it is not surprising to find the old names still in use, though in some cases they are not applied to the same things which they originally denoted. One of the illustrations of ancient water-marks given in the accounts of old paper, was in use as early as 1350, probably gave the name to what is called hand paper, fig. 550.

Another very favorite paper-mark, at a subsequent period 1540-60, was the jug or pot which is also shown, fig. 551, and would appear to have originated the term pot paper. The foolscap was a later device, and does not appear to have been nearly of such long continuance as the former, fig. 552. It has given place to the figure of Britannia, or that of a lion rampant, supporting the cap of liberty on a pole. The name, however, has continued, and we still denominate paper of a particular size by the title of foolscap. The original figure has the cap and bells, of which we so often read in old plays and histories, as the particular head-dress of the fool, who at one time formed part of every great man's establishment.

The water-mark of a cap may sometimes be met with of a much simpler form than that just mentioned—frequently resembling the jockey caps of the present day, with a trilling ornamentation or addition to the upper part. The first edition of "Shakespeare," printed by Isaac Jaggard and Ed. Blount, 1623, will be found to contain this mark, interspersed with several others of a different character. No doubt the general use of the term cap to various papers of the present day owes its origin to marks of this description.

The term imper[ial was in all probability derived from the finest specimens of papyri, which were so called by the ancients.

Post paper seems to have derived its name from the post-horn, which at one time was
its distinguishing mark, *fig. 553*. It does not appear to have been used prior to the establishment of the general post-office, (1670,) when it became the custom to blow a horn,

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to which circumstance no doubt we may attribute its introduction. The mark is still frequently used, but the same change which has so much diminished the number of painted signs in the streets of our towns and cities, has nearly made paper-marks a matter of antiquarian curiosity; the maker's name being now generally used, and the mark, in the few instances where it still remains, serving the purpose of mere ornament, rather than that of distinction.

Water-marks, however, have at various periods been the means of detecting frauds, forgeries and impositions, in our courts of law and elsewhere, to say nothing of the protection they afford in the instances already referred to, such as bank notes, cheques, receipt, bill, and postage stamps. The celebrated Curran once distinguished himself in a case which he had undertaken by shrewdly referring to the water-mark, which effectually determined the verdict. And another instance, which may be introduced in the form of an amusing anecdote, occurred once at Messina, where the monks of a certain monastery exhibited, with great triumph, a letter as being written by the Virgin Mary with her own hand. Unluckily for them, however, this was not, as it easily might have been, written upon the ancient papyrus, but on paper made of rags. On one occasion a visitor, to whom this was shown, observed, with affected solemnity, that the letter involved also a *miracle*, for the paper on which it was written was not in existence until several centuries after the mother of our Lord had died.

A further illustration of the kind occurs in a work entitled "Ireland's Confessions," which was published respecting his fabrication of the Shakespeare manuscripts,—a literary forgery even still more remarkable than that which is said to have been perpetrated by Chatterton, as Rowe's Poems.

The interest which at the time was universally felt in this production of Ireland's may be partially gathered from the fact, that the whole of the original edition, which appeared in the form of a shilling pamphlet, was disposed of in a few hours; while so great was the eagerness to obtain copies afterwards, that single impressions were sold in an auction room at the extravagant price of a guinea.

This gentleman tells us, at one part of his explanation, that the sheet of paper which he used was the outside of several others, on some of which accounts had been kept in the
reign of Charles the First; and being at that time wholly unacquainted with the water-marks used in the reign of Queen Elizabeth, "I carefully selected (says he) two half sheets, not having any mark whatever, on which I penned my first effusion." A few pages farther on he writes—"Being thus urged forward to the production of more manuscripts, it became necessary that I should possess a sufficient quantity of old paper to enable me to proceed; in consequence of which I applied to a bookseller named Verey in great May's Buildings, St. Martin's Lane, who, for the sum of five shillings, suffered me to take from all the folio and quarto volumes in his shop the fly leaves which they contained. By this means I was amply stored with that commodity; nor did I fear any mention of the circumstance by Mr. Verey, whose quiet, unsuspecting disposition, I was well convinced, would never lead him to make the transaction public, in addition to which he was not likely even to know anything concerning the supposed Shaksperian discovery by myself, and even if he had, I do not imagine that my purchase of the old paper in question would have excited in him the smallest degree of suspicion. As I was fully aware, from the variety of water-marks which are in existence at the present day, that they must have constantly been altered since the period of Elizabeth, and being for some time wholly unacquainted with the water-marks of that age, I very carefully produced my first specimens of the writing on such sheets of old paper as had no mark whatever. Having heard it frequently stated that the appearance of such marks on the papers would have greatly tended to establish their validity, I listened attentively to every remark which was made upon the subject, and from thence I at length gleaned the intelligence that a jug was the prevalent water-mark of the reign of Elizabeth, in consequence of which I inspected all the sheets of old paper then in my possession, and having selected such as had the jug upon them, I produced the succeeding manuscripts upon these, being careful, however, to mingle with them a certain number of blank leaves, that the production on a sudden of so many water-marks might not excite suspicion in the breasts of those persons who were most conversant with the manuscripts." 

Thus, this notorious literary forgery, through the cunning ingenuity of the perpetrator, united proved so successful as to deceive many learned and able critics of the age. Indeed, on one occasion, a kind of certificate was drawn up, stating that the undersigned names were affixed by gentlemen who entertained no doubt whatever as to the validity of the Shaksperian production, and that they voluntarily gave such public testimony of their convictions upon the subject. To this document several names were appended by persons as conspicuous for their condition as they were pertinacious in their opinions.

The water-mark in the form of a letter p, of which an illustration is given fig. 554, was taken from Caxton's well-known work, "The Game of the Chess," a fac-simile of which has recently been published as a tribute to his memory. Paper was made expressly for the purpose, in exact representation of the original, and containing this water-mark, which will be found common in works printed by him.

The ordinary mode of effecting such paper-marks as we have been describing is that of affixing a stout wire in the form of any object to be represented to the surface of the fine wire-gauze, of which the hand-mould, or machine dandy roller, is constructed.

The perfection, however, to which water-marks have now attained, which in many instances is really very beautiful, is owing to a more ingenious method recently patented, and since adopted by the Bank of England, as affording considerable protection to the public in determining the genuinities of a bank-note.

To produce a line water-mark of any autograph or crest, we might either engrave the pattern or device first in some yielding surface, precisely as we should engrave a copper-plate for printing, and afterwards, by immersing the plate in a solution of sulphate of copper, and electrotyping it in the usual way, allow the interspaces of the engraving to give as it were a casting of pure copper, and thus an exact representation of the original device, which, upon being removed from the plate, and affixed to the surface of the wire-gauze forming the mould, would produce a corresponding impression in the paper: or, supposing perfect identity to be essential, as in the case of a bank-note, we might engrave the design upon the surface of a steel die, taking care to cut those parts in the die deepest which are intended to give greater effect in the paper, and then, after having hardened, and otherwise properly prepared the die, it would be placed under a steam hammer or other stamping apparatus, for the purpose of producing what is technically termed a "force," which is required to assist in transferring an impression from the die to a plate of sheet brass. This being done, the die, with the mould-plate in it, would next be taken to a perforating or cutting machine, where the back of the mould-plate—that is, the portion which projects above the face of the die—would be removed, while that portion which was impressed into the design engraved would remain untouched, and this, being subsequently taken from the interspaces of the die and placed in a frame upon a backing of fine wire-cloth, becomes a mould for the manufacture of paper of the pattern which is desired, or for the production of any water-mark, autograph, crest, or device, however complicated.

A sheet and a half may be occasioned by a very similar process, but one which perhaps requires a little more care, and necessarily becomes somewhat more tedious. For instance, in the
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former ease the pulp is distributed equally throughout the entire surface of the wire forming the mould; whereas now we have to confine the means of increasing to a very great nicety the thickness or distribution of the pulp, and at the same time to make provision for the water's draining away. This has been accomplished by first taking an electrotype of the raised surface of any model or design, and again from that forming in a similar manner a matrix or mould, both of which are subsequently mounted upon lead or gutta percha, in order that they may withstand the pressure which is required to be put upon them in giving impression to a sheet of very fine copper wire-gauze, which, in the form of a mould, and in the hands of the valmar, suffices ultimately to produce those beautiful transparent effects in paper pulp. The word "Five" in the centre of the Bank of England note is produced in the same manner. The deepest shadows in the water-mark being occasioned by the deepest engraving upon the die, the lightest by the shallowest, and so forth; the die being employed to give impression by means of the stamping press and "force" to the fine wire-gauze itself, which by this means, providing the die be properly cut, is accomplished far more successfully than by any other process, and with the additional advantage of securing perfect identity. It may be interesting to call attention to the contrast as regards the method of mould-making originally practised, and that which has recently been adopted by the Bank of England. In a pair of five-pound note moulds, prepared by the old process, there were 8 curved borders, 16 figures, 168 large waves, and 240 letters, which had all to be separately covered by the finest wire to the waved surface. There were 1,056 wires, 67,584 twists, and the same repetition where the stout wires were introduced to support the under surface. Therefore, with the backing, laying, large waves, figures, letters, and borders, before a pair of moulds was completed, there were some hundreds of thousands of stitches, most of which are now avoided by the new patent. But further, by this multitudinous stitching and sewing, the parts were never placed precisely in the same position, and the water-mark was consequently different. Now, the same die gives impress to the metal which transfers it to the water-mark, with a certainty of identity unattainable before, and one could almost say, never to be surpassed.

And may we not detect principles in this process which are not only valuable to the Bank, but to all public establishments having important documents on paper; for what can exceed the value of such a test for discovering the deceptions of dishonest men? One's signature or stamp of oneself, serving the paper, exclusively one's own, can now be secured in a pair of moulds, at the cost merely of a few guineas. Manufactured paper, independently of the miscellaneous kinds, such as blotting, filtering, and the like, which are rendered absorbent by the free use of woollen rags, may be divided into three distinct classes, viz. writing, printing, and wrapping. The former again into fine, cream wove, yellow wove, blue wove, cream laid, and blue laid. The printing into two, laid and wove, and the latter into four, blue, purple, brown, and whitened brown, as it is commonly termed.

To obtain a simple definition of the mode adopted for distinguishing the various kinds, we must include, with the class denominated writing papers, those which are used for drawing, which being sized in like manner, and with the exception of one or two larger kinds, of precision, have the same dimness of appearance by the same name which are used strictly for writing purposes, (the only distinction, in fact, being, that the drawings are cream wove, while the writings are laid,) there would be of course be no necessity for separating them. Indeed, since many of the sizes used for printing are exactly the same as those which would be named as writing papers, for the sake of abbreviation we will reduce the distinctions of difference to but two heads, fine and coarse; under the latter including the ordinary brown papers, the whited brown, or small hand quality, and the blues and purples used by grocers. The smallest size of the fine quality, as sent from the mill, measures 12½ by 15 inches, and is termed post; next to that foolscap, 16½ by 13½; then post, 18½ by 15½; copy, 20 by 16½; large post, 20½ by 16½; medium post, 18 by 22½; sheet-and-third foolscap, 22½ by 14½; sheet-and-half foolscap, 24½ by 14½; double foolscap, 25 by 17; double post, 30½ by 22; double crown, 20 by 30; demy, 20 by 15½; ditto printing, 22½ by 17½; medium, 22 by 17½; ditto printing, 23 by 18½; royal, 24 by 19; ditto printing, 25 by 20; super royal, 27 by 19; ditto printing, 21 by 27; imperial, 30 by 22; elephant, 28 by 23; atlas, 34 by 26; columbia, 34½ by 23½; double elephant, 26½ by 40; and antiquarian, 53 by 31. The different sizes of letter and note paper ordinarily used are prepared from those kinds by the stationer, whose business consists chiefly in smoothing the edges of the paper, and afterwards packing it up in some tasteful form, which serves to attract attention. Under the characteristic names of coarse papers may be mentioned Kent cap, 21 by 18; bag cap, 19½ by 24; Havon cap, 21 by 26; imperial cap, 22½ by 29; double 2½, 17 by 24; double 4-lb., 21 by 31; double 6-lb., 19 by 28; casing of various dimensions, also cartriges, with other descriptive names, besides middle hand, 21 by 16;疫情影响 hand, 16½ by 21½; royal hand, 20 by 25; double small hand, 19 by 29; and of the purples, such specifications as copy loof, 16½ by 21½; 38-lb.; powder loof, 18 by 26, 58½-lb.; double loof, 16½ by 25, 48½-lb.; single loof, 21½ by 27, 75-lb.; lump, 23 by 33, 100-lb.; Hambro', 16½ by 23, 48½-lb.;
PAPIER-MÂCHE.

The origin of the manufacture of articles for use or ornament from paper, is not very clearly made out; we are naturally led to believe, from the name, that the French must have introduced it. We find, however, a French writer ascribes the merit of producing paper ornaments to the English.

A kind of papier-mâché has been introduced, called fibrous slab; for the preparation of this important material the coarse varieties of fibre only are required. These are heated and subjected to much agitation, to secure the reduction of the fibre to the proper size. This being effected, the pulp is removed and subjected to the action of the desiccating apparatus, or centrifugal drying machine. By the means of this apparatus the water is driven, by the action of the centrifugal force, from the fibre, and the pulp can thus be obtained in a few minutes of an equal and proper degree of dryness, and this without the application of any heat. The mass thus obtained may be regarded as a true pulp.

This fibrous pulp is next combined with some earthy matter to ensure its solidity, and certain chemical preparations are introduced, for the double purpose of preserving it from the attacks of insects and to ensure its incombustibility. The whole being mixed with a cementing size, is well kneaded together, steam being applied during the process. While the process is going forward, an iron table running on wheels is properly adjusted and covered with a sail-cloth; this table being arranged so that it passes under an immense iron roller. The fibrous mixture is removed from the kneading troughs and is laid in a tolerably uniform mass upon the sail-cloth, so as to cover about one-half of the table; over this again is placed a length of sail-cloth equal to that of the entire slab, as before. This being done, the table and roller are set in action, and the mass passes between them. It is thus squeezed out to a perfectly uniform thickness, and is spread over the whole table. The fibrous slab is passed through the rollers some three or four times, and it is then drawn off upon a frame fixed upon wheels prepared to receive it, by means of which it can be removed to the drying ground. The drying process of course varies much with the temperature and dryness of the air. It does not appear necessary that these slabs should dry too quickly, and there are many reasons why the process should not be prolonged.

We tried an experiment upon the non-inflammability of this material, by having a fire of wood made upon a slab and maintained there some time. When the ashes, still in a state of vivid combustion, were swept away, the slab was found to be merely charred by the intense heat. Beyond this, a piece of fibrous slab was thrown into the middle of the fire, and the flames were urged upon it; under the influence of this intense action it did not appear possible to kindle it into a flame; it smouldered very slowly, the organic matter charring, but nothing more.

* For further information upon this point, see the "Practical Guide to the Varieties and Relative Values of Paper." Longman & Co.
The Fibrous Slab Company is certainly producing a material which, in many of its applications, must prove of the greatest utility, while great additional value is given to it from the circumstance of its resisting the attacks of insects, and being non-inflammable, under any of the ordinary operations of combustion.

Papier-Mâché may be said, therefore, to consist of three varieties:—1. Sheets of paper pasted together, exposed to great pressure, and then polished; 2. Sheets of considerable thickness, made from ordinary paper pulp; and 3. Such as we have described in a manufacture of the fibrous slab,—E. J. II.

A new composition has recently (1858) been patented by Mr. John Cordery Martin, which he designates a “Plastic compound for the manufacture of articles in imitation of wood carvings, &c.” The patentee thus describes his process, and the resulting material:—

“The object I have had in view is the production of a plastic compound applicable to the manufacture of moulded articles, which, when hardened, resembles wood in the closeness of its texture and fibrous character throughout, and is particularly applicable to the manufacture of articles intended to imitate wood carvings. The new manufacture may also be called ceramic paper-mâché, from the wax-like character of the compound when in a soft state, or before hardening. The compound consists of twenty-eight parts (dry) by weight of paper pulp, or of any fibrous substances of which paper may be made, reduced to pulp by means of an ordinary beating engine, or other means used for the manufacture of pulp; twenty parts of resin, or resin, or pitch, or other resinous substance. I prefer resin or resin; ten parts of soda or potash, to render the resin soluble; twenty-four parts of glue, twelve parts of drying oil, and one part of acetate or sugar of lead, or other substances capable of hardening or drying oil. The pulp after leaving the beating engine is to be drained and slightly pressed under a screw or press, to free it partially from water. The resin and alkali are then to be boiled or heated together and well mixed. The glue is to be broken up in pieces and melted in a separate vessel with as much water as will cover it, and then to be added to the resin and alkali, which mixture is then to be added to the pulp and thoroughly incorporated with it. The acetate of lead well mixed in the oil is then to be added, and the whole mass or compound is then to be thoroughly mixed. The quantity of resin and alkali, in proportion to the glue used, might vary, or glue might even be dispensed with when the acetate of lead would be proportionately increased. After mixing the compound, it is to remain exposed to the air for three or four days before using, and to be continually turned to free it from some of its moisture, for the purpose of partially drying, when it is to be well kneaded, and again exposed to the air for a few hours; and this operation of kneading and partial drying may be repeated until the compound is considered to be sufficiently stiff and plastic, as, during the process of kneading or working together, it becomes extremely plastic, resembling from this quality, when sufficiently kneaded, wax or clay, and it may then be worked, pressed, or moulded into any required form. The compound may be kept in a plastic state for some weeks, or even months before using, if required, by keeping it from exposure to the air and occasionally kneading or working it together. The moulds should, previous to pressing therein the compound, be brushed with oil, or with oil in which is mixed a little acetate of lead. The article taken from the mould is to be thoroughly dried, and afterwards it may be baked in an oven at a moderate heat, the temperature to be low at first, and gradually increased, care being taken not to scour or injure the fibres of the compound. The plastic compound so made and treated acquires many of the peculiarities of wood, as regards hardness and strength, and it may be cut, or carved and polished, if required. Any color may be added to the compound when in a soft state, or two or more portions of the compound, stained with different colors, may be worked together to form a grain to more nearly imitate the appearance of wood. The use of the alkali being to render the resinous substance sufficiently soluble to combine with the wet pulp, a more or less quantity than that given in proportion to the resin may be used, according to the degree of solubility thought to be necessary. When potash is used, it may be dissolved in water before being heated with the resin. The quantity of glue may vary, and may be increased to twice the quantity of resin, or even more, or sufficiently so as to dispense with the acetate of lead, as it gives hardness, and with oil prevets the compound from sticking; but mixed in this manner it cannot be so well kneaded, and does not retain so fine an impression. I prefer using with the ingredients as above mentioned the acetate of lead; but half a part by weight of a solution of sulphuric or other acid, diluted with twenty times its volume of water, may be substituted for the one part of acetate of lead. The oil mixed with the other ingredients is used to prevent the compound from adhering to the surface of the mould, but the less oil consistently with this object that is used, the better. Only half the proportion of oil stated to be used as above may be added at the time of mixing the ingredients of the compound, and the remainder may be added during the process of kneading or working up the mass. I wish it to be understood, although I prefer to use resin or resin or pitch to form the compound, that other resinous bodies soluble with alkalis may be used, as the gums copal, mastic, elemi, inc., Canadian balsam, Venice turpentine, or other resinous bodies of a like kind, either separately, or mixed according to the facility...
with which they will combine with wet pulp, and the convenience with which the compound may be worked, as will be well understood by persons conversant with these substances.

PARAFFINE; from *parum affinis*, indicating the want of affinity which this substance exhibits to most other bodies.

Paraffine is a white substance, void of taste and smell, feels soft between the fingers, has a specific gravity of 0.87, melts at 112° Fahr., boils at a higher temperature with the exhalation of white fumes, is not decomposed by dry distillation, burns with a clear white flame, without smoke or residuum, does not stain paper, and consists of 85-32 carbon, and 14.78 hydrogen; having the same composition as olefiant gas. It is decomposed neither by cold, nor strong acids, nor potassium; and unites by fusion with sulphur, phosphorus, wax, and resin. It dissolves readily in warm fat oils, in cold essential oils, and in ether, but sparingly in boiling absolute alcohol. Paraffine is a singular solid blearuret of hydrogen. It has been obtained by the destructive distillation of peat.

The solid obtained is manufactured into beautiful candles, not more than 300 tons, however, being employed annually in this manufacture. See NAPHTHA; MINERAL CANDLES; PEAT; DISTILLATION, DESTRUCTIVE.

PARCHMENT, VEGETABLE. Vegetable parchment is made from waterleaf or un-sized paper, of which ordinary blotting paper is a common example, and is well adapted for the process. This is manufactured from rags of linen and cotton, thoroughly torn to pieces in the pulping machine, and it is found that long fibrous paper is not so good for the production of vegetable parchment as that which is more thoroughly pulped. The structure of the waterleaf may be regarded as an interlacement of vegetable fibres in every direction, simply held together by contact, and consequently offering a vast extension of surface and minute may here to favor capillary action.

To make vegetable parchment, the waterleaf or blotting paper is dipped in diluted sulphuric acid, when the change takes place, and though nothing appears to be added or subtracted, the waterleaf loses all its previous properties and becomes vegetable parchment.

This very remarkable transformation is, however, a most delicate chemical process. The strength of the acid must be regulated to the greatest nicety, for if on the one hand it is too dilute, the fibre of the paper is converted into a soluble substance, probably dextrin, and its paper-like properties are destroyed. If, however, the acid be too strong, it also destroys the paper and renders it useless.

For the most perfect result, the sulphuric acid and water should be at ordinary temperature in the proportion of about two volumes of oil of vitriol and one volume of water, and if the paper be simply immerse before immersion, the strength of the acid is altered at these spots, and the part so acted upon is destroyed.

To make vegetable parchment, the waterleaf is dipped in the sulphuric acid exactly diluted to the desired strength, when in the course of a few seconds the paper will be observed to have undergone a manifest change, by which time the transformation is effected in all its essential points. The acid has then done its work, and is to be thoroughly removed from the paper, firstly by repeated washings in water, and subsequently by the use of very dilute ammonia to neutralize any faint trace of acid which escapes the washing in water. All minute traces of sulphate of ammonia left by the former process are removed as far as possible by further washings, and in certain cases the infinitesimal trace of ammonia may be removed by lime or baryta.

The action and intent of these several processes are to render the vegetable parchment perfectly free from any acid or salt, and the object is thoroughly obtained in the large way.

When the paper has undergone its metamorphosis, it is simply dried, when it becomes vegetable parchment, differing from blotting paper, and possessing peculiarities which separate it from every other known material. The surfaces of the paper appear to have undergone a complete change of structure and composition. All the cavities of the waterleaf are closed, and the surface is solidified to such an extent, that if a portion of vegetable parchment be heated over a flame, blisters will occur from pent-up steam, which are evolved in the centre of the paper, and even in the aerial state the vapor cannot pass either surface. The material of the metamorphosed surfaces is certainly one of the most unalterable and unchangeable of all known organic substances and requires a distinctive name to indicate its individuality.

From Dr. Hofmann's report on this remarkable substance we extract the following remarks:

"In accordance with your request, I have carefully examined the new material, called vegetable parchment, or parchment paper, which you have submitted to me for experiment, and I now beg to communicate to you the results at which I have arrived.

I purpose to state that the article in question is by no means new to me; I became acquainted with this remarkable production very soon after Mr. W. E. Gaine had made known his results, and I have now specimens before me which came into my possession as early as 1854.

The substance submitted to me for examination exhibits in most of its properties so
PARCHMENT, VEGETABLE.

close an analogy with animal membrane, that the name adopted for the new material seems fully justified. In its appearance, vegetable parchment greatly resembles animal parchment; the same peculiar tint, the same degree of translucency, the same transition from the fibrous to the hornlike condition. Vegetable, like animal parchment, possesses a high degree of cohesion, bearing frequently-repeated bending and rewinding without showing any tendency to break in the folds; like the latter, it is highly hygroscopic, acquiring by the absorption of moisture increased flexibility and toughness. Immersed in water, vegetable parchment exhibits all the characters of animal membrane, becoming soft and slippery by the action of the water, without, however, losing in any way its strength. Water does not permeate through vegetable parchment, although it slowly traverses this substance like animal membrane by endosmotic action.

"In converting unsized paper into vegetable parchment or parchment paper by the process recommended by Mr. Gaine, viz. immersion for a few seconds in oil of vitriol diluted with half its volume of water, I was struck by the observation, how narrow are the limits of dilution between which the experiment is attended with success. By using an acid containing a trifle more of water than the proportion indicated, the resulting parchment is exceedingly imperfect; whilst too concentrated an acid either dissolves or chars the paper. Time, also, and temperature are very important elements in the successful execution of the process. If the acid bath be only slightly warmer than the common temperature, 60° F. (15° C.)—such as may happen when the mixture of acid and water has not been allowed sufficiently to cool—the effect is very considerably modified. Nor do the relations usually observed between time, temperature, and concentration, appear to obtain with reference to this process; for an acid of inferior strength, when heated above the common temperature, or allowed to act for a longer time, entirely fails to produce the desired result. Altogether, the transformation of ordinary paper into vegetable parchment is an operation of considerable delicacy, requiring a great deal of practice; in fact, it was not until repeated failures had pointed out to me the several conditions involved in this reaction, that I succeeded in producing papers in any way similar to those which you have submitted to me for experiment.

"It is obvious that the transformation, under the influence of sulphuric acid, of paper into vegetable parchment, is altogether different from the changes which vegetable fibre suffers by the action of nitric acid; the cellulose receiving, during its transition into pararabdina and gum-cotton, the elements of hypornitric acid in exchange for hydrogen, whereby its weight is raised, in some cases by forty, in others, by as much as sixty per cent. As the nitro-compounds thus produced differ so essentially in composition from the original cellulose, we are not surprised to find them also endowed with properties altogether different; such as, increased combustibility, change of electrical condition, altered deportment with solvents, &c., whilst vegetable parchment, being the result of a molecular transposition only, in which the paper has lost nothing and gained nothing, retains all the leading characters of vegetable fibre, exhibiting only certain modifications which confer additional value upon the original substance.

"The nature of the reaction which gives rise to the formation of vegetable parchment having been satisfactorily established, it became a matter of importance to ascertain whether the processes used for the mechanical removal of sulphuric acid from the paper had been sufficient to produce the desired effect. It is obvious that the valuable properties acquired by paper, by its conversion into vegetable parchment, can be permanently secured only by the entire absence or perfect neutralization of the agent which produced them. The presence of even traces of free sulphuric acid in the paper would rapidly loosen its texture, the paper would gradually fall to pieces, and one of the most important applications which suggest themselves, viz. the use of vegetable parchment in the place of animal parchment for legal documents, would thus, at once, be lost. The paper was found to be entirely free from this acid.

"The absence of free sulphuric acid in the parchment paper was, moreover, established by direct experiment. The most delicate test papers left for hours in contact with moistened vegetable parchment, did not exhibit the slightest change of color. For this purpose, bands of vegetable and of animal parchment, both ½ of an inch in width, and as far as possible of equal thickness, were slung round an horizontal cylinder, and appropriately fixed by means of a screw-clamp pressing both ends upon the upper part of the cylinder. The band assumed in this manner the shape of a ring, into the bend of which a small cylinder of wood was placed, projecting on each side about an inch over the band, and carrying, by means of strings fastened to each end, a pan which was loaded with weights until the band gave way. A set of experiments made in this manner led to the following result:—

<table>
<thead>
<tr>
<th>Weight Loaded</th>
<th>Waterleaf Paper Broke</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 lb.</td>
<td></td>
<td>13 lb.</td>
</tr>
<tr>
<td>13 lb.</td>
<td></td>
<td>13 lb.</td>
</tr>
<tr>
<td>7 lb.</td>
<td></td>
<td>7 lb.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weight Loaded</th>
<th>Vegetable Parchment Broke</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 lb.</td>
<td></td>
<td>7 lb.</td>
</tr>
<tr>
<td>70 lb.</td>
<td></td>
<td>70 lb.</td>
</tr>
</tbody>
</table>

The results are as follows:—

Waterleaf paper broke, when loaded with 17 lb., 13 lb., and 7 lb., respectively; the parchment paper broke, when loaded with 7 lb. and 70 lb., respectively. It will be seen that the parchment paper broke at a much greater weight than the waterleaf paper.
PEAT AND TURF.

Animal parchment broke, when loaded with

\[
\begin{array}{llll}
\text{L.} & \text{92lb.} & \text{m.} & \text{Mean.} \\
\text{L.} & \text{75lb.} & \text{50lb.} & 75lb. \\
\end{array}
\]

The strips of vegetable and animal parchment were selected as nearly as possible of equal thickness, but the strips of the artificial product were somewhat heavier than those of real parchment. On an average the former weighed 18 grains, and the latter only 12-75 grains. Calculated for equal weights, the strength of animal parchment, as compared with that of artificial parchment, is obviously \( \frac{18}{12.75 \times 75} = 105 \). In round numbers, it may be said that vegetable parchment has three-fourths the strength of animal parchment.

PEAT AND TURF. Accumulations of vegetable matter may be chiefly composed either of succulent vegetation, grasses, or marsh plants, or of trees; and the structure and condition of woody fibre is well known to be very different from that of grasses and succulent plants. There are thus two very distinct kinds of material preserved, the one undergoing change much less rapidly than the other, and perhaps much less completely. It is easily proved that from the accumulation of forest trees has been obtained the imperfect coal called lignite, while from marsh plants and grasses mixed occasionally with wood we obtain peat, turf, and bog. All these substances consist to a great extent of carbon, the proportions amounting to from 50 to 60 per cent., and being generally greater in lignite than in turf. On the other hand, the proportion of oxygen gas is generally very much greater in turf than in lignite. The proportion of ash is too variable to be worth recording, but is generally sufficiently large to injure the quality of the fuel.

As a very large quantity of turf exists in Ireland, covering, indeed, as much as one seventh part of the island, the usual and important practical condition of this substance can be best illustrated by a reference to that country. This will be understood by the following account of its origin, abstracted from the "Bog Report" of Mr. Nimmo. He says, referring to cases where clay spread over gravel has produced a kind of peat in preventing the escape of waters of floods or springs, and when muddy pools have thus been formed, that aquatic plants have gradually crept in from the borders of the pool towards their deep centre. Mud accumulated round their roots and stalks, and a spongy semi-fluid was thus formed, well fitted for the growth of moss, which now especially appears; Sphagnum began to luxuriate, this absorbing a large quantity of water, and continuing to shoot out new plants above, while the old were decaying, rotting and compressing into a solid substance below, gradually replaced the water by a mass of vegetable matter. In this manner the marsh might be filled up while the central or moister portion, continuing to excite a more rapid growth of the moss, would be gradually raised above the edges, until the whole surface had attained an elevation sufficient to discharge the surface water by existing channels of drainage, and calculated by its slope to facilitate their passage, when a limit would be, in some degree, set to its further increase. Springs existing under the bog or in its immediate vicinity might indeed still favor its growth, though in a decreasing ratio; and here if the water proceeding from them were so obstructed as to accumulate at its base, and to keep it in a rotten fluid state, the surface of the bog might be ultimately so raised, and its continuity below so totally destroyed, as to cause it to flow over the retaining obstacle and flood the adjacent country. In mountain districts the progress of the phenomenon is similar. Pools indeed cannot in so many instances be formed, the steep slopes facilitating drainage, but the clouds and mists resting on the summits and sides of mountains, amply supply their surface with moisture, which comes, too, in the most favorable form for vegetation, not in a sudden torrent, but unceasingly and gently, drop by drop. The extent of such bogs is also affected by the nature of the rocks below them. On quartz they are shallow and small; on any rock yielding by its decomposition a clayey coating they are considerable; the thickness of the bog, for example, in Knocklaid in the county of Antrim (which is 168 feet high), being nearly 12 feet. The summit bogs of high mountains are distinguishable from those of lower levels by the total absence of large trees.

As turf includes a mass of plants in different stages of decomposition, its aspect and constitution vary very much. Near the surface it is light colored, spongy, and contains the vegetable matter but little altered; deeper, it is brown, denser, and more decomposed; and finally at the base of the greater bogs, some of which present a depth of 40 feet, the mass of turf assumes the black color and nearly the density of coal, to which also it approximates very much in chemical composition. The amount of ash contained in turf is also variable, and appears to increase in proportion as we descend. Thus, in the section of a bog 40 feet deep at Tamah, those portions near the surface contained 1% per cent. of ashes, the centre portions 31 2/10 per cent., whilst the lowest four feet of turf contained 19 per cent. of ashes. In the superficial layers it may also be remarked, that the composition is nearly the same as that of wood, the succulent material being lost, and in the lower we find the change still more complete. Notwithstanding these extreme variations, we may yet establish the ordinary constitution of turf, and with this knowledge construct the practice of use, and on the average specimens of turf selected from various localities, the following results have been obtained:
The calorific power of dry turf is about half that of coal; it yields, when ignited with lead, about 14 times its weight of lead. This power is however immensely diminished in ordinary use by the water which is allowed to remain in its texture, and which the spongy character of its mass renders it very difficult to get rid of. There is nothing which requires more attention than the collection and preparation of turf; indeed, for practical purposes, this valuable fuel is absolutely spoiled as it is now prepared in Ireland. It is cut in a wet season of the year; whilst drying, it is exposed to the weather; it hence is in reality not dried at all. It is very usual to find the turf of commerce containing one-fourth of its weight of water, although it then feels dry to the hand. But let us examine what effects the calorific power. One pound of pure dry turf will evaporate 6 lbs. of water; now, in 1 lb. of turf as usually found, there are 4 lbs. of dry turf, and 3 lbs. of water. The 4 lbs. can only evaporate 4 1/3 lbs. of water; but out of this it must first evaporate the 4 lbs. contained in its mass, and hence the water boiled away by such turf is reduced to 3 1/3 lbs. The loss is here 39 per cent. — a proportion which makes all the difference between a good fuel and one almost unfit for use. When turf is dried in the air under cover it still retains one-tenth of its weight of water, which reduces its calorific power 12 per cent., 1 lb. of such turf evaporating 3 1/3 lbs. of water. This effect is sufficient, however, for the great majority of objects; the further desiccation is too expensive, and too troublesome to be used, except in special cases.

The characteristic fault of turf as a fuel is its want of density, which renders it difficult to concentrate, within a limited space, the quantity of heat necessary for many operations. The manner of heating turf is indeed just the opposite to anthracite. The turf yields a vast body of volatile inflammable ingredients, which pass into the flues and chimney, and thus distribute the heat of combustion over a great space, whilst in no one point is the heat intense. Hence for all flaming fires turf is applicable; there is, however, as some experiments made on Dartmoor show, some liability to that burning away of the metal which may arise from the local intensity of coke. If it be required, it is quite possible to obtain a very intense heat with turf.

The removal of the porosity and elasticity of turf, so that it may assume the solidity of coal, has been the object of many who have proposed mechanical and other processes for the purpose. It has been found that the elasticity of the turf fibre presents great obstacles to compression, and the black turf, which is not fibrous, is of itself sufficiently dense. Not merely may we utilize turf in its natural condition, or compressed or impregnated pitchy matter, but we may carbonize it, as we do wood, and prepare turf charcoal, the properties of which it is important to establish. — 1. By heating turf in close vessels; by this mode loss is avoided, but it is expensive, and there is no compensation in the distilled liquors, which do not contain acetic acid in any quantity. The tar is often small in proportion, hence the charcoal is the only valuable product. Its quantity varies from 50 to 40 per cent. of dry turf. The products of the distillation of 1,157 lbs. of turf were found by Blavier to be, charcoal, 474 lbs., or 41 per cent.; watery liquid, 226 lbs., or 19 3/4 per cent.; gaseous matter, 450 lbs., or 39 per cent.; and tar, 7 lbs., or 6 per cent.; but the proportion of tar is variable, sometimes reaching 24 5/7 per cent. when the turf is cooked in close vessels.

The economical carbonization of turf is best carried on in heaps, in the same manner as that of wood. The heaps must be carefully arranged, and laid as close as possible; they are the better for being large, 15 inches long, by 6 broad, and 5 deep. The heaps built hemispherically should be smaller in size than the heaps of wood usually are. In general, 5,000 or 6,000 large soda may go to the heap, which will thus contain 1,500 cubic feet. The mass must be allowed to heat more than is necessary for wood, and the process requires to be very carefully attended to, from the extreme combustibility of the charcoal. The quantity of charcoal obtained in this mode of carbonization is from 25 to 30 per cent. of the weight of dry turf.

For many industrial uses the charcoal so prepared is too light, as, generally speaking, it is only with fuel of considerable density that the most intense heat can be produced, but by coking compressed turf, it has already been shown, that the resulting charcoal may attain a density of 1,940, which is far superior to wood charcoal, and even equal to that of the best coke made from coal. As to calorific effects, turf charcoal is about the same as coal coke, and little inferior to wood charcoal.

It is peculiarly important, in the preparation of the charcoal from the turf, that the material should be selected as free as possible from earthy impurities, for all such are concentrated in the coke, which may be thereby rendered of little comparative value. Hence, the coke from surface turf contains less than 10 per cent. of ash, whilst that of dense turf of lower strata contains from 20 to 30 per cent. This latter quantity might altogether unfit it for practical purposes. — Ashed.

Peat is cut and prepared in a very simple manner. The surface matter being removed, a peculiar kind of spade called a spade is employed. This is a long spade with a portion of the blade turned up at right angles on one side. With this the turf is cut out in the shape
of thick bricks: these are piled loosely against each other to dry. The longer peat is kept, and allowed to dry, the more important it becomes as a heating agent.

On Dartmoor the peat is cut by the convicts, working in gangs, and being dried, it is carefully stored in one of the old prisons. From this peat, by a most simple process, gas is made, with which the prisons at Prince Town are lighted. The illuminating power of this gas is very high. The charcoal left after the separation of the gas is used in the same establishment for fuel, and for sanitary purposes, and the ashes eventually go to improve the cultivated lands of that bleak region. Attempts were made here many years since to distil the peat for naphtha, paraffine, &c., but the experiments not proving successful, the establishment was abandoned.

Experiments of a similar character have been made in Ireland, especially by a company working under the patents of Mr. Rees Reece. A Government Commission made their Report on these experiments. The whole matter was so ably examined by Sir Robert Kane (Director of the Museum of Irish Industry), and by his assistant, Dr. Sullivan, that we quote somewhat largely from their Report.

The object being to ascertain the necessary facts regarding the products of commercial value, the following was the course pursued:—

Specimens of turf representing the several ordinary varieties were separately experimented on, and the results examined.

The products of the distillation were collected as—

1. Charcoal.
2. Tar.
3. Watery liquids.
4. Gases.

The relative quantities produced by 100 parts of peat were found to be—

<table>
<thead>
<tr>
<th>Product</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal</td>
<td>29-222</td>
<td>39-132</td>
<td>18-973</td>
</tr>
<tr>
<td>Tar products</td>
<td>27-87</td>
<td>44-17</td>
<td>1-942</td>
</tr>
<tr>
<td>Watery products</td>
<td>31-378</td>
<td>38-127</td>
<td>21-819</td>
</tr>
<tr>
<td>Gases</td>
<td>36-016</td>
<td>57-746</td>
<td>25-018</td>
</tr>
</tbody>
</table>

The peats yielding those proportions of products had been found to contain previous to distillation, as dried in the air, a quantity of hygrometric moisture, and to yield a proportion of ashes in 100 parts as follows:—

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashes</td>
<td>19-71</td>
<td>29-50</td>
<td>16-39</td>
</tr>
<tr>
<td></td>
<td>3-43</td>
<td>7-90</td>
<td>1-99</td>
</tr>
</tbody>
</table>

The several products of the distillation thus carried on were next specially examined for the several materials of which the quantities and commercial value had been the principal sources of the public interest of this inquiry.

The inquiry having reference, however, to the technical objects of the process, was carried on by examining the produce of

I. Tar for—
1. Volatile oils.
2. Fixed (less volatile) oils.
3. Solid fats, or paraffine.

II. Watery liquids for—
1. Acetic acid.
2. Ammonia.
3. Pyroxylic spirit.

III. Gases for illuminating and heating power.

The following numbers will indicate the results obtained in average. All the details of the processes of separation, and the numbers of the individual experiments, were given in special reports.

In seven series of distillations in close vessels, there was obtained from 100 parts of peat:

<table>
<thead>
<tr>
<th>Product</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>0-208</td>
<td>0-181</td>
<td>0-404</td>
</tr>
<tr>
<td>or as</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphate of ammonia</td>
<td>1-037</td>
<td>0-702</td>
<td>1-367</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>0-101</td>
<td>0-076</td>
<td>0-286</td>
</tr>
<tr>
<td>or as</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetate of Lime</td>
<td>0-280</td>
<td>0-111</td>
<td>0-419</td>
</tr>
<tr>
<td>Pyroxylic spirit</td>
<td>0-146</td>
<td>0-092</td>
<td>0-197</td>
</tr>
<tr>
<td>Volatile oils</td>
<td>0-790</td>
<td>0-571</td>
<td>1-282</td>
</tr>
<tr>
<td>Fixed oils</td>
<td>0-550</td>
<td>0-266</td>
<td>0-760</td>
</tr>
<tr>
<td>Paraffine</td>
<td>0-164</td>
<td>0-024</td>
<td>0-196</td>
</tr>
</tbody>
</table>
It is thus seen that the proportions of these products vary within wide limits, which are determined by differences of quality of the turf or temperature in the distillation.

Several trials were made to determine the amount of kerosene present in the tar, but although its presence could be recognized, its proportion was so minute as to render its quantitative estimation impossible. This circumstance constitutes an essential distinction of peat-tar from wood-tar, and indicates for the former an inferior commercial value, as the presence of kerosene, now so extensively employed, is an element in the estimate of the price of the tar obtained by distilling wood.

"It will be understood," writes Sir Robert Kane, "that the materials indicated in the foregoing table by the names 'fixed and volatile oils' are in reality mixtures of a variety of chemical substances of different volatilities and compositions—generally carbo-hydrogens—of which the further separation would be a labor of purely scientific curiosity, without having any bearing upon the objects of the present report. Although, therefore, these liquids were carefully examined, and observations made regarding their chemical history, I shall not embarras the present report by reference to them in any other point of view than as products of destructive distillation whose properties, analogous to the highly volatile and to the fixed oils respectively, may give them a commercial value such as has been represented. I may remark also, that as a purely scientific question, the true nature of the solid fatty product is of much interest. The name paraffine has been given to this body, but in some of its characters it appears to deviate from those of the true paraffine, as described by Reichenbach to be obtained from wood-tar; those differences should, however, not contravene its commercial use." See Paraffine.

The inquiry so far carried on sufficiently established that the peat by destructive distillation in close vessels yielded the several products that had been described, and were identical, or closely analogous, to those afforded in the distillation of wood or coal. The process in close retorts, however, being not at all that proposed or economically practicable for commercial purposes, it was necessary to proceed to determine whether the same varieties of peat, being distilled in a blast furnace, with a current of air, so that the heat necessary for the distillation was produced by the combustion of the peat itself, would furnish the same products, and whether in greater or in less quantities than in the process in close vessels.

For this purpose, the cylinder which in the former series of experiments had been set horizontally in the furnace, was placed surrounded by brickwork vertically, its mouth projecting a little at top, so that the tube for conveying away the products of the distillation passed horizontally from the top of the brickwork casing to the condensing apparatus. Near the bottom of the cylinder the brickwork left a space where the cylinder was perforated by an aperture 1 inch diameter, to which the tube of a large forge bellows was adapted. The arrangement thus represented nearly the construction of an iron eupola. The cylinder being charged with peat, of which some fragments were first introduced lighted, and the blast being put on, the combustion spread, and the cover of the cylinder being screwed down, the distillation proceeded, the products passing over with the current of air into the series of condensing vessels, and the gases and air finally being conducted by a waste pipe to the ashpit of a furnace where they were allowed to escape.

By this means there was obtained, on a moderate scale, a satisfactory representation of the condition of air-blast distillation of peat which has been proposed as the commercial process. In so carrying it on several interesting observations were made which will require to be noticed here in a general point of view.

First, as to the nature and quantities of the products. The specimens of peat operated on were selected as similar to those employed in the former series of which the results have been quoted, and the products similarly treated were found to be, from 100 parts—

<table>
<thead>
<tr>
<th>Product</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watery products</td>
<td>30714</td>
<td>38738</td>
<td>29818</td>
</tr>
<tr>
<td>Tarry products</td>
<td>2392</td>
<td>2910</td>
<td>2270</td>
</tr>
<tr>
<td>Gases</td>
<td>62392</td>
<td>69041</td>
<td>59716</td>
</tr>
<tr>
<td>Ashes</td>
<td>4197</td>
<td>7236</td>
<td>2493</td>
</tr>
</tbody>
</table>

These several products having been further examined, as in the former case, gave from 100 parts of peat—

<table>
<thead>
<tr>
<th>Product</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia or as</td>
<td>0.237</td>
<td>0.344</td>
<td>0.194</td>
</tr>
<tr>
<td>Sulphate of ammonia</td>
<td>1.110</td>
<td>1.330</td>
<td>0.745</td>
</tr>
<tr>
<td>Acetic acid or as</td>
<td>0.207</td>
<td>0.268</td>
<td>0.174</td>
</tr>
<tr>
<td>Acetate of lime</td>
<td>0.305</td>
<td>0.303</td>
<td>0.256</td>
</tr>
<tr>
<td>Pyroxylic spirit</td>
<td>0.140</td>
<td>0.158</td>
<td>0.106</td>
</tr>
<tr>
<td>Volatile oils</td>
<td>1.059</td>
<td>1.220</td>
<td>0.946</td>
</tr>
<tr>
<td>Paraffine</td>
<td>0.125</td>
<td>0.169</td>
<td>0.086</td>
</tr>
</tbody>
</table>
"It is now important to compare these average results with those of the former series obtained by distillation in close vessels: we obtain—

<table>
<thead>
<tr>
<th></th>
<th>Average produce from</th>
<th>Average produce by</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>close distillation.</td>
<td>air-blast distillation.</td>
</tr>
<tr>
<td>Ammonia</td>
<td>-</td>
<td>0.268</td>
</tr>
<tr>
<td>or as</td>
<td>-</td>
<td>1.110</td>
</tr>
<tr>
<td>Sulphate of ammonia</td>
<td>-</td>
<td>0.191</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>-</td>
<td>0.207</td>
</tr>
<tr>
<td>or as</td>
<td>-</td>
<td>0.207</td>
</tr>
<tr>
<td>Acetate of lime</td>
<td>-</td>
<td>0.250</td>
</tr>
<tr>
<td>Pyroxylic spirit</td>
<td>-</td>
<td>0.146</td>
</tr>
<tr>
<td>Oils</td>
<td>-</td>
<td>1.340</td>
</tr>
<tr>
<td>Paraffine</td>
<td>-</td>
<td>0.134</td>
</tr>
</tbody>
</table>

Experiments were made at the request of Sir Robert Kane, by Dr. Hodges, Professor of Agriculture, to determine the commercial value of the peat products.

The quantities and nature of the products, as certified by Mr. Hodges, in the one trial which he superintended, compared with the Museum average results reduced to the same standard (Dr. Hodges' acetic acid having been 25 per cent. of real) are—

<table>
<thead>
<tr>
<th></th>
<th>Professor Hodges.</th>
<th>Museum.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From 100 parts.</td>
<td>From 100 parts.</td>
</tr>
<tr>
<td>Sulphate of ammonia</td>
<td>222 lbs.</td>
<td>1'000 lbs.</td>
</tr>
<tr>
<td>Acetic acid real hydrated</td>
<td>74 lbs.</td>
<td>4(\frac{1}{2}) lbs.</td>
</tr>
<tr>
<td>Wood naphtha</td>
<td>83(\frac{1}{4}) oz.</td>
<td>50(\frac{1}{2}) oz.</td>
</tr>
<tr>
<td>Tar</td>
<td>99(\frac{1}{2}) lbs.</td>
<td>53(\frac{3}{4}) lbs.</td>
</tr>
</tbody>
</table>

It hence is evident that the quantity of ammonia obtained at Newtown Crommelin is rather under that obtained at the Museum; but the produce of acetic acid, tar, and naphtha, has been found in average decidedly inferior to that stated, although the maximum results found in particular trials have approximated closely to Dr. Hodges' numerical results. There having been, however, apparently but a single trial so accurately followed up at Newtown Crommelin, it is necessary to contrast the results of the Museum experiments more specially with the quantitative produce expected by Mr. Reece.

Mr. Reece's statement of the produce from 100 tons of peat distilled is compared with the average results of the Museum trials in the following table:

<table>
<thead>
<tr>
<th></th>
<th>From 100 parts of peat.</th>
<th>Average results of Museum trials by blast process.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphate of ammonia</td>
<td>1'000</td>
<td>1'110</td>
</tr>
<tr>
<td>Acetate of lime</td>
<td>700</td>
<td>305</td>
</tr>
<tr>
<td>Wood naphtha</td>
<td>185</td>
<td>140</td>
</tr>
<tr>
<td>Paraffine</td>
<td>704</td>
<td>125</td>
</tr>
<tr>
<td>Fixed oils</td>
<td>714</td>
<td>1'099</td>
</tr>
<tr>
<td>Volatile oils</td>
<td>557</td>
<td></td>
</tr>
</tbody>
</table>

From this comparison it is evident that the quantity of ammonia obtained is rather greater than that expected by Mr. Reece; secondly, that the quantity of paraffine and of oils may be considered the same; thirdly, that the quantity of wood-naphtha expected by Mr. Reece is more than was obtained in average, but not more than was obtained in some Museum trials. That the quantity of acetate of lime expected by Mr. Reece is more than double that which was in average obtained in the Museum, unless the commercial acetate of lime calculated for by Mr. Reece shall contain such excess of lime, &c., as shall render its weight double that which the pure article, calculated in the result of the Museum trials, should have. This latter circumstance may possibly explain the difference.

After a minute detail of the numerous experiments made by Dr. W. Sullivan, in the Laboratory of the Museum of Irish Industry, Sir Robert Kane gives the following summary of his results:

"From these considerations of the results of the experiments made in the Museum of Industry, and the trials at Newtown Crommelin, and of the circumstances of the manufacture of the same products from the other species of fuels by processes more or less analogous, it appears to me that some general conclusions may be deduced:—

1. That the quantities of ammonia, of wood spirit, and of so-called paraffine, fixed and volatile oils, stated by Mr. Reece to be obtained by distillation from peat, do not appear to be exaggerated, as they fall within the limits of the results obtained in the Museum laboratory, and approach closely to the average results. That the quantity of acetic acid or acetate of lime, stated by Mr. Reece and Dr. Hodges, could not be obtained, the result of the Museum trials affording but from one-half to two-thirds of the expected quantity of that substance. That, further, the produce of paraffine may possibly be rendered much more considerable than was stated by Mr. Reece, through a more judicious treatment of the resinous materials of the tar than had been proposed by that chemist."
"2. That the distillation with combustion of the peat in the blast furnaces must be considered to produce only the raw materials for the subsequent chemical operations, just as in the processes of wood or coal distillations, there are produced tar and ammonia, and acetic acid, which have long been the objects of manufacture.

"3. That those materials, if charged with the total cost of the peat consumed, the cost of erecting and working the furnaces, the blast engines, and condensing apparatus, and proportion of management, would not appear to be very much more economically obtained from peat, than they are now obtained from the products of wood and coal distillation, where they are sold at very low prices, and, at least as regards gas tar and gas liquor, in most places in Ireland, have been regarded as waste products.

"4. That the principal value of the class of products obtained from peat is derived from the cost of their subsequent purification and conversion into a commercial form, and that consequently the principal advantage of a new mode of obtaining them must be looked for in the more economical treatment of those materials.

"5. That to this principle the extraction of the paraffine may be an exception, it being itself a material new to commerce on a large scale, and hence not having its value determined by the comparative economy of preparation from sources of little value.

"6. That the economies introduced in the treatment of the tarry and watery products of peat distillation are reducible to two (so far as I have been able to learn):—1, the separation of the wood spirit, by means of an improved distilling apparatus; and 2, the utilization of the waste gases from the condensing pipes, so as to supersede the use of other fuel by burning the gas in jets under the steam boilers, tar and acetic acid stills, evaporating pans, &c.

"7. That the former economy cannot be of paramount influence, as it affects but one stage in the preparation of a single product, and further might be applied in a similar way to lessen the cost of production of wood spirit from any other source.

"8. That the latter economy is of the most important character, and appears more than any other one condition to influence the probable success of the manufacture on the great scale; that therefore the amount of advantage derived from similar employment of gases in iron-smelting works will deserve careful comparison, and that it will be necessary particularly to take into account the difference of combustibility of gaseous mixtures when very hot, as when from an iron furnace, and when quite cold, as from the condensing apparatus of a peat blast furnace.

"9. That under the circumstances of a manufacture presenting so many new and complex processes, which, in analogous branches of industry, it is found convenient to separate and commit to different and individual interests, and that its conditions, as to the supply of peat, require its establishment in localities of but little industrial activity, it can scarcely be expected that even as much economy and advantage should be realized as might be expected after experience of the same processes on a working scale and with trained labor.

"10. That although the excessive returns stated by the proposers of the manufacture may not be obtained, it is yet probable that, conducted with economy and the attention of individual interests, the difficulties connected with so great complexity of operations would be overcome, and the manufacture be found in practice profitable; and certainly it must be regarded as of very great interest and public utility that a branch of scientific manufacture should be established, specially adapted to promote the industrial progress of Ireland by conferring a commercial value on a material which has hitherto been principally a reproach, and by affording employment of a remunerative and instructive character to our laboring population.

PENCIL MANUFACTURE. (Crayons, fabrique de, Fr.; Bleistiftes verfertigung, Germ.)

The word pencil is used in two senses. It signifies either a small hair brush employed by painters in oil and water-colors, or a slender cylinder of black lead or plumago, either naked or enclosed in a wooden case, for drawing black lines upon paper. The last sort, which is the one to be considered here, corresponds nearly to the French term crayon, though this includes also pencils made of differently colored earthy compositions.

The best black-lead pencils of this country are formed of slender paralleloipeds, cut out by a saw, from sound pieces of plumago, especially such as have been obtained from Borrowdale, in Cumberland. These paralleloipeds are generally enclosed in cases made of cedar wood, though of late years they are also used alone, under the name of ever-pointed pencils, in peculiar pencil-cases, provided with an iron wire and screw, to protrude a minute portion of the plumago beyond the tubular metallic case, in proportion as it is wanted.

Pieces of plumago sufficiently large to be thus employed are very rare, and the supply from the Cumberland mine can no longer be relied on. The mine has been closed for some years, but during the past year (1859) a company has been formed for again working it. Many attempts have been made to utilize the smaller fragments of plumago by grinding them, melting them with sulphur or antimony, and the like; but few of these have been attended with any success.

The late Mr. Brockedon was long occupied in seeking for some method which might enable him to employ the pure powder of black lead without cementing it by any sub-
stance, which inevitably injures the quality. He endeavored to render the powder coherently by submitting it to enormous pressure; but the different machines and apparatus he at first made use of for this purpose, however strongly they were made, were broken under the pressure, and his endeavors were thus unsuccessful, until the happy idea suggested itself of operating in a vacuum. But it was with extreme difficulty, if not impossible, to introduce under the receiver of an air pump an apparatus for compressing the powder of graphite. Mr. Brockedon overcame this difficulty by an arrangement as simple as it is easily executed; for, after having compacted the powder by a moderate pressure, and thus reduced it to a certain size, he enclosed it in very thin paper glued over the whole surface. He then pierced it in one place with a small round hole permitting the escape of the air from within, when the block thus prepared was placed under an exhausted receiver, and the air having been removed, the orifice was closed with a little piece of paper (a small adhesive wafer was usually employed for this purpose), and in this state it was found that it might be left for 24 hours without injury. Being submitted to a regulated pressure once more, the different particles became agglomerated, and an artificial block of graphite was produced by simple pressure, as solid as the specimens obtained from the mine.

The artificial masses of plumago thus obtained owed much of their character to the extreme fineness to which the plumago was reduced by previous grinding under rollers. In this manner a great deal of useless plumago is worked up into excellent black-lead pencils. The different degrees of darkness in drawing pencils should be secured by the selection of specimens of plumago of varying degrees of density. It is, however, commonly obtained by combusting with the plumago, sulphur, or sulphuret of antimony, and by subjecting the plumago to the action of heat. In the commoner kinds of pencil a very heterogeneous mixture is employed; indeed, many pencils are little more than black chalks.

The description of the pencil at Keswick, given in Chambers' Journal, in 1848, is so graphic and correct that we do not hesitate to transfer much of it to these pages.

The factory consists of a house of several stories, in the lower of which is a large water-wheel turned by the Greta, outside being the cedar wood ready for use. The quantity of cedar consumed annually by the establishment is not quite equal to the whole tree. Three cedar logs are sawed into planks, and then a circular saw cuts the planks into smaller pieces, preparatory to the grooving engine; this grooving engine consists of two revolving saws, going at inconceivable speed; one saw cutting the slips of wood into narrow square rods, and the other making a groove along the rod and cutting to size at the same time; adjoining the grooving apparatus is a circular saw, cutting slips of cedar as covers to the grooved lengths.

The plumago, if good, needs no refining; it is used precisely in the condition in which it leaves the mine. To ascertain its qualities each piece is scraped with the edge of a knife, besides being otherwise tested; and in proportion as there is no gritty particles in it, so is it the more valuable. Some pieces are harder, some a little darker in color, than others; and according to these peculiarities, they are employed for pencils of various hardness and shades. The whole knack of pencil-making seems to depend on the detection of these niceties in the quality of the wood, and also, of course, in their honest adaptation to the various sizes dealt out to the public. Plumago of an impure kind is ground to powder; the grit, as far as possible, separated from it, and the cleansed material, mingled with a cohesive liquid, is dried and pressed into hard lumps for use. This process, however, is applied principally, if not exclusively, to the plumago imported from India, and only in reference to pencils of the commonest sort. Pencils made with such stuff are valueless to artists; for independently of their want of tone, they are never altogether free from grit. The only good pencil is one made from genuine Borrowdale lead, pure from the mine, and adapted by a skilful manufacturer to its assigned purpose. The mode of preparing the pieces of good plumago for the pencil is very simple. All the bits, with their surface merely scraped, are glued to a board, in order to fix them in a position for being sawn. When so fixed they are brought under the action of a saw, which divides them into thin slices or scallings. These slices are now handed to the fitter. This is an operative who, with a lot of grooved rods before him, sticks slices of the lead into grooves, snipping off each slice level with the surface, so as to leave the groove properly filled. In the making of a single pencil, perhaps as many as three or four slice lengths are required; but however many, each slice is fitted exactly endlong with another, so as to leave no intervals. The rods being thus filled, are carried to the fastener-up. This person glues the cedar covers or slips over the filled rods; and having got a certain number arranged alongside of each other, he fixes them tightly together, and lays them aside to dry. When dried they are ready for being rounded. The rounding is done by an apparatus fixed to a bench—a thing of revolving planes or turning tools. Into this engine, rods are put one after another, and out they come as fast as the eye can follow them, rounded to a perfect nicety. By this simple and efficient machine a man will round from six hundred to eight hundred dozens of pencils in a day. After being rounded they get a smoothing with a plane, and then they are polished by being rubbed with a peculiar kind of fishskin; this latter operation being performed by girls. Being polished, the next step is to cut the rods into lengths with a circular saw.
after which the lengths are respectively smoothed at the ends. Nothing now remains but to stamp the name of the maker, with the letters significant of their quality. The stamping engine is as ingenious a piece of machinery as is in the establishment. Fed into it, the pencils are stamped in less than an instant of time. A girl will do this apparatus stamp two hundred pencils per minute. Gathered from a box below into which the pencils fall, they are carried away to be tied in bundles.

PERFUMERY, ART OF. (Parfumerie, Fr.; Wohlriechende-Kunst, Germ.) consists in the extraction of the odors of plants, isolating them, A and B—and in combining them with inodorous materials; such as grease, C, spirit, D, starch, E, soaps, F; also in the manufacture of cosmetics, G, dentifices, pastes, tinctures, H, incense and pastils, I, pomades, oils, and other toilet appendages, K, hair washes, hair dyes, depilatories, L.

(A and B) There are three distinct methods of procuring the odors of plants. 1st. By Distillation. If cloves, cinnamon bark, or the odorous leaves of plants or wood, be distilled, the fragrant principle contained therein rises with the steam, which, being condensed, the otto, or essential oil, will be found floating upon the water. This process has already been described (see Distillation, Otto); but can only be beneficially applied by the perfumer to the procuring of certain odors: from woods, such as sandal and cedar; from leaves, such as patchouli and bay leaves; from various grasses, such as the lemon grass and citronella of Ceylon; from the several seeds, such as caraway and nutmeg; and but to two or three flowers, such as orange blossom, rose, and lavender. The various fragrant woods, seeds, and leaves are, however, almost as numerous as there are plants upon the earth, and as a consequence, the perfumer can have as great a variety of ottoys by distilling for them.

(C.) 2d. Enfleurage. When it is desired to obtain the odors of flowers, such as those of jasmine, acacia, violet, tuberose, jonquil, and numerous others, the process of distillation is inapplicable and useless, and that peculiar but simple method, termed "Enfleurage," must be adopted. This plan is founded on the fact that greasy bodies readily absorb odorous particles, and will as freely part with them if in contact with pure alcohol. The operation of enfleurage is thus conducted at Messrs. Pisse and Latbin's laboratory of flowers, near Nice, in Sardinia (now France, 1860).

Purification of the grease. A corps, or body grease, is first produced by melting together equal parts of deer or beef suet (the former is preferred), mutton suet, and lard; it is then clarified thus:—take 1 cwt. of grease, divide it into portions of about 2 lbs., place one of these in a mortar and well pound it; when it is well crushed wash it with water repeatedly, so long, in fact, until the water is as clear, after withdrawing the grease, as before it was put in. The several lots of grease prepared in this way have now to be melted over a slow fire, adding thereto about 3 ounces of crystallized alum in powder and a handful of sea salt (common salt); now let the grease boil, but allow it to bubble for a few seconds only; then strain the grease through a fine linen into a deep pan and allow it to stand to clear itself from impurities for about two or three hours. The clear grease is then again put into the melting vessel over a charcoal fire, adding thereto about three or four quarts of rose water and half a pound of powdered gum benzoin; it is then allowed to boil gently, and all scum that rises carefully removed until it ceases to be produced. Finally, the grease is poured into deep pans to cool; when sold it is removed off the sedimentary water, and again being filtered may be placed in store vessels for future use, where it may be kept for an indefinite period without change or becoming rancid. This purification of the grease gives employment to those engaged in the laboratory at a season when the flowers are not in bloom. M. Herman, of Cannes, and M. Pilar, of Grasse, prepare in this way during winter, together, one hundred and twenty thousand pounds of perfectly inodorous grease.

The growers of the flowers, of course, pay due attention to their cultivation, so as to produce an abundance of blossom in due season. Although it is not necessary that the flower farmer should be a perfumery factor, it is useful that the latter should have some knowledge of the former avenir, so as to be prepared for each harvest of flowers as they succeed each other; and when it is practicable to unite the occupations, better pecuniary results follow. At Cannes and Grasse, in France, which are separated from the frontier of Sardinia only by the river Var, and are distant from Nice about 30 miles, the entire population is more or less interested in this particular manufacture. The various flowers there cultivated do not come into blossom at one time, but in succession; so that there is ample time to attend to each in turn.

The enfleurage process is thus conducted:—Square frames varying in size from 20 to 30 inches are made, in the centre of which is fixed a piece of stout glass as in fig. 555. Each frame is 11 inch deep from the top edge to the glass, so that if two frames be placed together face to face, there is, as it were, a glass box with a wooden frame, having a depth of 3 inches between each glass. This affords ample room for the blossoms to lie between them without being crushed. In due
PHOSPHORUS, AMORPHOUS.

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season, that is, when the flowers begin to bloom, about half a pound of the purified grease is spread upon each side of the glass with a spatula or pallet knife. The gathered blossoms are then hand-sprinkled or broad-cast over the grease in one frame, and another frame is put over it so as to enclose the flowers. This operation is repeated as many times as there are flowers to spread over each. These frames are termed chasé, which literally means "Sash." Now, we are all familiar with window sashes—that is, a glass with a frame round it—and such is in truth the chasé used in the enfleurage process. Doubtless our window "sash" is derived from the French. Chasé may also be rendered in English, "a frame." Enfleurage, then, is conducted upon a glass frame or sash. About every other day, or every third day, the spent flowers being thrown away, fresh ones are placed upon the grease; this manipulation being repeated as long as the plants yield blossoms, a time that varies from one to two months. After every addition of flowers, it will be observed that the grease increases in the fragrance of the flower with which it was sprinkled, and this continues till the enfleurage is complete, at which time the grease, now called "Pomade," is scraped off the sashes, put into vessels, then placed in hot water—a water bath. By so doing the pomade is liquified, but is not made hot enough to destroy its odor. By this treatment various extraneous matters, such as a few anthers of flowers, a stray bee, some pistils, or loose part of the corolla, a wayward butterfly and moth, and such similar things, are removed, by pouring the clear pomade into the canisters through fine linen. When the pomade is cold enough it sets in these vessels, and is then fit for exportation or for interior uses. Fig. 555 represents a pile of chassé.

3. Maceration. In some few instances better results are obtained by adopting the process of maceration, which consists in infusing the fresh flowers in liquefied grease. For this purpose, the purified grease is placed in a hot-water bath, that is, the vessel containing the grease is set in another of a larger size, in which water is kept warmed over a stove. In the French laboratories, this apparatus is known as the haute marie, salt being put into the water to increase its boiling point. Every time fresh flowers are gathered the spent ones are strained away, and the fresh flowers put into the partially scented grease. In a few instances it is found advantageous to begin perfuming the grease by maceration, and to finally finish it by enfleurage; this is especially the case with violet pomade.

After the maceration is completed, that is, when there are no more flowers to be had, the grease must be kept steadily at a uniform degree of liquefaction, in order that friable portions of the flowers, &c., may subside, so that the fair pomade can be separated from pure and unassilled. Oils are scented by enfleurage and maceration processes by a slight difference of mechanical arrangement. Thus, the sash in lieu of glass contains a wire gauze, like a coarse wire blind (chaisé en fer); upon this gauze is laid a thick piece of fastidiously clean cotton fabric (molleton du coton), which has previously been steeped in the purest olive oil. Upon each molleton laid in the sash frame the flowers are sprinkled in the same way as if it were for pomade, and the flowers are changed as often as possible. When the plants cease to boom, each molleton is wrapped in a strong cord net, and placed in a hydraulic or other press, for the purpose of squeezing the fragrant oil away from it. Oils of tuberosa, rose, violet, jonquil, senna, and orange are thus prepared.

According to the length of time the enfleurage process occupies, and the quantity of flowers employed over the same grease, the pomade or oil bears numbers respectively. Thus we have No 12 pomade, No 18 oil, No 24 pomade, indicating their relative strength of fragrance, that is, the quantity of flowers employed in their manufacture.

PERNAMBUCO WOOD. See Brazil Wood.

PETWORTH MARBLE. A shelly limestone, occurring in the Wealden strata, in the neighborhood of Petworth, in Sussex. H. W. B.

PHOSPHORUS, AMORPHOUS; or Red Phosphorus. If a stick of phosphorus be put into a hermetically closed tube and exposed to the action of the spectrum, one end will become white and the other red. It may be prepared also by exposing phosphorus for a long time in an atmosphere quite free of oxygen or moisture, to a temperature of 470° F. At this temperature, the phosphorus fuses; it remains for some time colorless, and then gradually becomes red and opaque. Amorphous phosphorus was investigated by Dr. Schröter, of Vienna. The apparatus for making it consists of a double iron pan; the intermediate space between the two contains a metallic bath of an alloy of tin and lead; with a
PHOTOGEN.

cast-iron cover to the inner vessel, fitted to the top end by means of a screw, and fastened to the outer vessel by screw pins. In the interior iron vessel a glass vessel is fitted, in which the phosphorus to be operated upon is placed. From this inner vessel a tube passes, and is dipped into water to serve as a safety valve. A spirit lamp is applied under that pipe if necessary, to prevent its being clogged with phosphorus. The phosphorus to be converted is first of all mixed and then cooled under water, and dried as much as possible. A fire is now made under the other vessel, and the temperature raised to such a degree as to drive off the air, &c. The temperature has to be gradually raised, until bubbles escape at the end of the pipe, which take fire as they enter the air, and the heat may soon rise in the bath till it be 470° F. This temperature must be maintained for a certain time to be determined by experience; the apparatus may then be allowed to cool. The converted phosphorus is difficult to detach from the glass. It is to be levigated under water, and then drained in a bag. The phosphorus when moist should be spread thinly on separate shallow trays of sheet iron or lead, so placed alongside each other as to receive the heat of steam, and lastly of chloride of calcium or of sand, till the phosphorus having been frequently stirred, shows no more luminous vapor. The operator should have water at hand to quench any fire that might arise. It is then to be washed till the water shows no trace of acid. Should the resulting phosphorus contain some of the unconverted article, this may be removed by bisulphuret of carbon. Thus, heat alone effects the transmutation. It is identical in composition with ordinary phosphorus, and may be reconverted into it without loss of weight, and that merely by change of temperature. This substance remains unaltered in the atmosphere, is insoluble in sulphuret of carbon, in alcohol, ether, and naphtha. It requires a heat of 200° C. to restore it to the ordinary state, and it is only at that heat that it begins to take fire in the open air. It is not luminous in the dark at any ordinary temperature. When perfectly dry, amorphous phosphorus is a scarlet, or carmine powder, which becomes darker when heated. On the large scale it is prepared in dark masses of a red or dark brown color. The great advantages of this singular condition of phosphorus are, that it does not appear to affect those persons who are employed in the manufacture of lucifer matches with the loathsome disease which the use of the ordinary phosphorus produces. See Lucifer Matches.

PHOTOGEN. Syn. Paraffine Oil. A term which has recently found its way into commerce, to designate certain oils or naphthas for illuminating purposes. It is generally prepared from shales, brown coals, or cannel. Boghead coal, and the numerous varieties of inflammable shales which more or less resemble it, are specially adapted for the preparation of photojen. The chief physical difference between photojen and ordinary coal oils of the same boiling point, is the specific gravity, which with the former varies from 0.820 to 0.850, whereas common coal naphtha never has a less density than 0.850°. It is true that photojen may be obtained of as high a density as 0.900, but then it will be of an excessively high boiling point, and, in all probability, saturated with paraflnine.

The light oil known as photejen may be obtained from common bituminous coals by distilling them at a lower temperature than is employed in gas works. To obtain the maximum amount of photojen from coal, the temperature should not be much above 700° C.

Preparation.—The coals broken in small pieces, the smaller the better, are to be heated in vertical or horizontal iron retorts, the tar being received through a very wide worm into large tanks. Some manufacturers use vertical, and others horizontal retorts; it is also common to distil the coals by the heat produced by their own combustion. If the latter process be employed, the arrangements for condensing the product must be very perfect, or great loss will be sustained, owing to the air which supports the combustion carrying away a considerable quantity of the hydrocarbons. This power of air to saturate itself with vapors, is of great importance in the economy of all processes where the distillation of one portion of substance is carried on by the heat evolved by the combustion of another. It is not uncommon in practice, where the cylinders are horizontal, to place the coal or other matters to be distilled in semi-cylindrical trays, which are capable of being inserted into the retorts, and also of being removed to make way for another charge at the completion of the operation.

The tar obtained by any of the above processes is to be redistilled; the lighter portions form (when purified by means of sulphuric acid and alkalis) the fluid known in commerce as "Boghead naphtha." See Naphtha. Boghead. In Germany and some other places, it is usual to divide the distillate from the tar into two portions, one being for the preparation of photojen, and the other for "solar oil." This division is made as the fluid runs from the still; the more volatile constituting the photojen, and the less the solar oil.

The process of purification is the same in both cases, namely, alternate treatments with concentrated sulphuric acid to remove the highly colored and odorous constituents of the crude distillate, and washing with an alkali to remove carboilic acid and its congeners; also that portion of sulphuric acid which remains suspended in the carbonic acid produced by the decomposition of a portion of the sulphuric acid by the carbon of certain easily decomposed organic matters in the crude distillate. This decomposition of the sulphuric acid happens thus:—

$$2SO_2 + 2H_2O = 2H_2SO_4.$$
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There is another advantage in the treatment of the fluid by alkalies, inasmuch as some sulphide of hydrogen, and probably other fixed sulphur compounds, is decomposed and the resulting products removed.

In preparing photogen from any of the sources enumerated, much must be left to the discretion of the manufacturer both as regards the apparatus and the chemical processes. In some instances the solar oil and photogen are with advantage prepared separately, but in this country it is more usual to mix the heavy and light oils together so as to produce a fluid of medium density and volatility. It must be remembered that while the more volatile hydrocarbons confer extreme inflammability and fluidity, they are at the same time more odorous than the less volatile portion of the distillate, which is the true paraffine oil.

The more odorous impurities in photogen appear to be easily susceptible of oxidation. This is evident from the facility with which foully smelling photogen loses its offensive odor in contact with bichromate or manganese of potash, or even animal charcoal. Their exposure to air even greatly improves the odor, and a recently distilled photogen, which is very unpleasant, becomes comparatively sweet if kept in tanks or barrels for a few days.

The same thing happens with many essential oils, such as those of peppermint, cloves, &c. The presence of sulphurous acid in photogen may be instantly detected by shaking a little in a test tube with a few drops of a very weak solution of bichromate of potash; if sulphurous acid be present a portion of the chromic acid will be reduced to green oxide, which will instantly betray the presence of the reducing agent alluded to.

Photogen often shows the phenomenon of dichroism, but the more it is purified by aids the more feebly is the coloration by reflected light observed, and if the less volatile portion of the distillate be rejected, the property alluded to will not be perceived.

In distilling the heavy oils or tars produced by distilling Boghead coal or other photogen-yielding substances, it is particularly to be observed that the worms or other tubes proceeding from the stills, if of too small diameter, are liable to become choked up with paraffine; this, unobserved, might lead to serious results. It is very convenient to have a steam pipe inserted into the worm tubes or condensing tanks, to enable the water to be heated to such a point as to melt any solid matters in the worms, and allow them to be washed into the recipient by the fluids distilling over.

None of the nannel or bituminous coal, shales, or other substances used for yielding burning fluid by distillation, gives distillates of such purity and freedom from odor as Rangoon tar. The more volatile portion of the distillate from the latter has obtained in commerce the absurd name of Sherwoodole; it is used instead of coal benzole, for removing grease, &c. The paraffine obtained from Rangoon tar has a greater value for commercial purposes than that from Boghead coal, inasmuch as it has a higher melting point, which renders it better adapted for candles. The following are the melting points of various samples of paraffine:

- Boghead coal paraffine
- The last, after being distilled
- Turf paraffine
- Bituminous coal paraffine, prepared by Atwood’s process
- Rangoon tar paraffine

It is curious to observe the effect of light upon photogen. Some samples of extremely dark color, when exposed to its influence for a few days, become as completely bleached as animal oils would under these circumstances. At the same time, as we have before hinted, the odor becomes much improved. A photogen of good quality has by no means a repulsive odor, but if much of the more volatile constituents be present, it is impossible to avoid its being disagreeable if spilled about. The less volatile hydrocarbons have comparatively little odor. It should not be too inflammable, that is to say, it must not take fire on the approach of a light. If it does, it is owing to the more volatile portion not having been sufficiently removed.—C. G. W.

PHOTOGRAPHIC ENGRAVING. The first who appears to have had any idea of heliographic engraving was Niepce Nèpée. According to M. Aime Girard the first proof taken by him by means of this process bears date 1827, some dozen years before the publication of Mr. Talbot’s Photogenic processes. This process, which is now almost forgotten, was very simple; it consisted in spreading a thin layer of bitumen of Judea upon a copper or pewter plate, which was then placed in the camera obscura, where it was allowed to remain some hours, until it had received the impression of the external objects towards which the lens had been directed. On withdrawing the plate it was submitted to the action of the essence of lavender, which dissolved the portions of the bitumen not acted upon by the light, leaving the metal bare, while the remaining bitumen reproduced the design. Passing the plate afterwards through an acid solution it was found that it had eaten hollows in the metallic plate, while the other parts were preserved by the protecting varnish. Such was the process that M. Nèpée revealed to Daguerre when he entered into a partnership
with him. Niepce died in 1833, after struggling twenty years, during which he spent his time and money in endeavoring to perfect his discovery, poor and almost unknown.

Six years later, that is in 1839, M. Daguerre made his discovery public. In the mean time he had considerably improved on Niepce's process; but the introduction of the Calotype led to the abandonment of the process for some years.

The next process to which we shall refer is that of M. Fizeau. He took a daguerreotype plate and submitted it to the action of a mixture of nitric, nitrous, and hydrochloric acids, which did not affect the whites of the picture but attacked the blacks with a resulting formation of adherent chloride of silver, which specially arrested the action of the acid. This he removed by a solution of ammonia, and the action of the acid was continued. This process he continued until a finely engraved plate was the result; but the lines of this plate were not deep enough to allow of prints being taken from it; and to remedy this, he covered the plate with some drying oil, and then, wiping it from the surface, left it to dry in the hollows. He afterwards submitted the plate to an electro-chemical process which covered the raised parts with gold, leaving the hollows in which the varnish remained untouched. On the completion of the gilding this varnish was removed by means of caustic potash, and the surface of the plate covered with grumes de gravure, producing what is technically termed an aquatint ground, and the deepening of the lines was proceeded with by means of the acid. The Daguerreotype plate was by these means converted into an engraved plate, but as it was silver it would have worn out very soon; to facilitate which an impression was taken on copper by an electro-chemical process, which could of course be renewed when it showed signs of wear.

M. Claudet and Mr. Grove both produced some very beautiful engravings on the Daguerreotype plate, but as these processes have proved rather curious than useful, they need not be described.

On the 29th of Oct., 1852, Mr. Fox Talbot patented a process, which was similar to the Photogalvanographic process previously used by MM. Pretsch and Poitevin, as regards the substance first used, viz., a mixture of bichromate of potash and gelatine; but the remaining portion of the process was conducted on the same principle, though in a different manner, to that of M. Fizeau.

Mr. Mungo Ponton discovered the use of the bichromate of potash as a photographic agent, and Mr. Robert Hunt subsequently published a process, called the "Chromotype.

In both these processes the peculiar property of the chronic acid liberated under the action of sunshine, to combine with organic matter, was pointed out. MM. Pretsch, Poitevin, and Talbot only availed themselves of this previous discovery, and in each instance gelatine was rendered insoluble by the decomposition of the bichromate of potash under the influence of elettic power. By dissolving off the still soluble portions of the gelatine, either metal could be precipitated by the voltaic battery, or an etching produced.

In 1853 M. Niepce de St. Victor, the nephew of Niepce, took up his uncle's plan, and with the assistance of M. Lemaitre, who had also assisted his uncle, endeavored to perfect it; but though he modified and improved it, his success was not very great; it was always found necessary to have the assistance of an engraver to complete the plate.

After this many others, among whom may be enumerated MM. Lerebours, Lemercier, Barreswil, Davanne, and finally Poitevin, endeavored to obtain a design by similar means on stone. The last appears to have succeeded. His method is based on the chemical reaction of light on a mixture of gelatine and bichromate of potash, as above. This mixture, when made is perfectly soluble in water, becomes insoluble after exposure to the light. His mode of proceeding is as follows:—He spreads the mixture on the stone, and after drying lays the negative upon it and exposes it to the light. After a suitable exposure the negative is removed, and the portions not acted upon by the light are washed away with water, and the design remains with the property of taking the ink like an ordinary lithographic crayon. The stone is then transferred to the press and proofs taken in the usual way. It is said that excellent pictures have been obtained from the stone after 900 copies had been pulled.

The process of M. Charles Niegre, which has excited much attention in Paris, is more complicated than the preceding, but yields superior results. His process appears to be not unlike that of M. Fizeau. He employs acids to etch the lines into the plate, and at a certain stage of the process it is submitted to the action of a galvanic bath which plates it with copper, silver, or gold, according to circumstances. By his process the half-tones are produced with much delicacy.

Mr. Fox Talbot's process of Photographic Engraving has been thus described by himself:—

"I employ plates of steel, copper, or zinc, such as are commonly used by engravers. Before using a plate its surface should be well cleaned; it should then be rubbed with a linen cloth dipped in a mixture of caustic soda and whiting, in order to remove any remaining trace of greasiness. The plate is then to be rubbed dry with another linen cloth. This process is then to be repeated; after which, the plate is in general sufficiently clean.
PHOTOGRAPHIC ENGRAVING.

"In order to engrave a plate, I first cover it with a substance which is sensitive to light. This is prepared as follows:—About a quarter of an ounce of gelatine is dissolved in eight or ten ounces of water, by the aid of heat. To this solution is added about one ounce, by measure, of a saturated solution of bichromate of potash in water, and the mixture is strained through a linen cloth. The best sort of gelatine for the purpose is that used by cooks and confectioners, and commonly sold under the name of gelatine. In default of this, binglass may be used, but it does not answer so well. Some specimens of binglass have an acidity which slightly corrodes and injures the metal plates. If this accident occurs, ammonia should be added to the mixture, which will be found to correct it. This mixture of gelatine and bichromate of potash keeps good for several months, owing to the antiseptic and preserving power of the bichromate. It remains liquid and ready for use at any time during the summer months; but in cold weather it becomes a jelly, and has to be warmed before using it; it should be kept in a cupboard or dark place. The proportions given above are convenient, but they may be considerably varied without injuring the result. The engraving process should be carried on in a partially darkened room, and is performed as follows:—A little of this prepared gelatine is poured on the plate to be engraved, which is then held vertical, and the superfluous liquid allowed to drain off at one of the corners of the plate. It is held in a horizontal position over a spirit lamp, which soon dries the gelatine, which is left as a thin film, of a pale yellow color, covering the metallic surface, and generally bordered with several narrow bands of prismatic colors. These colors are of use to the operator, by enabling him to judge of the thinness of the film: when it is very thin, the prismatic colors are seen over the whole surface of the plate. Such plates often make excellent engravings; nevertheless, it is perhaps safer to make gelatine films which are a little thicker. Experience alone can guide the operator to the best result. The object to be engraved is then laid on the metal plate, and screwed down upon it in a photographic copying frame. Such objects may be either material substances, as lace, the leaves of plants, &c., or they may be engravings, or writings, or photographs, &c., &c. The plate bearing the object upon it is then to be placed in the sunshine, for a space of time varying from one to several minutes, according to circumstances; or else it may be placed in common daylight, but of course for a long time. As in other photographic processes, the judgment of the operator is here called into play, and his experience guides him as to the proper time of exposure to the light. When the frame is withdrawn from the light, and the object removed from the plate, a faint image is seen upon it—the yellow color of the gelatine having turned brown wherever the light has acted.

"The novelty of the present invention consists in the improved method by which the photographic image, obtained in the manner above described, is engraved upon the metal plate. The first of these improvements is as follows:—I formerly supposed that it was necessary to wash the plate, bearing the photographic image, in water, or in a mixture of water and alcohol, which dissolves only those portions of the gelatine on which the light has not acted; and I believe that all other persons who have employed this method of engraving, by means of gelatine and bichromate of potash, have followed the same method, viz., that of washing the photographic image. But however carefully this process is conducted, it is frequently found, when the plate is again dry, that a slight disturbance of the image has occurred which, of course, is injurious to the beauty of the result; and I have now ascertained that it is not at all necessary to wash the photographic image; on the contrary, much more beautiful engravings are obtained upon plates which have not been washed, because the more delicate lines and details of the picture have not been at all disturbed. The process which I now employ is as follows:—When the plate, bearing the photographic image, is removed from the copying frame, I spread over its surface, carefully and very evenly, a little finely-powdered gum copal (in default of which common resin may be employed). It is much easier to spread this resinous powder evenly upon the surface of gelatine, than it is to do so upon the naked surface of a metal plate. The chief error the operator has to guard against is, that of putting on too much of the powder: the best results are obtained by using a very thin layer of it, provided it is uniformly distributed. If too much of the powder is laid on it impedes the action of the etching liquid. When the plate has been thus very thinly powdered with copal, it is held horizontally over a spirit lamp in order to melt the copal; this requires a considerable heat; it might be supposed that this heating of the plate, after the formation of a delicate photographic image upon it, would disturb and injure that image; but it has no such effect. The melting of the copal is known by the change of color. The plate should then be withdrawn from the lamp, and cooled to cool. This process may be called the laying an aquatint ground upon the gelatine, and I believe it to be a new process. In the common mode of laying an aquatint ground, the resinous particles are laid upon the naked surface of the metal, before the engraving is commenced. The gelatine being thus covered with a layer of copal, disseminated uniformly and in minute particles, the etching liquid is to be poured on. This is prepared as follows:—Muriatic acid, otherwise called hydrochloric acid, is saturated with peroxide of iron, as much as it will dissolve with the aid of heat. After straining the solution, to remove
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impurities, it is evaporated till it is considerably reduced in volume, and is then poured off into bottles of a convenient capacity; as it cools it solidifies into a brown semi-crystalline mass. The bottles are then well corked up, and kept for use. I shall call this preparation of iron by the name of perchloride of iron in the present specification, as I believe it to be identical with the substance described by chemical authors under that name—for example, see Turner's Chemistry, fifth edition, page 597; and by others called permuriate of iron—for example, see Brand's Manual of Chemistry, second edition, vol. ii. page 117.

"It is a substance very attractive of moisture. When a little of it is taken from a bottle, in the form of a dry powder, and laid upon a plate, it quickly disseminates, absorbing the atmospheric moisture. In solution in water, it forms a yellow liquid in small thicknesses, but chemise-brown in greater thicknesses. In order to render its mode of action in photographic engraving more intelligible, I will first state, that it can be very usefully employed in common etching; that is to say, if a plate of copper, steel, or zinc is covered with an etching ground, and lines are traced on it with a needle's point, so as to form any artistic subject; then, if the solution of perchloride of iron is poured on it, it quickly effects an etching, and does this without disengaging bubbles of gas, or causing any smell; for which reason it is much more convenient to use than aquafortis, and also because it does not injure the work if a part, or its border, split upon the plate. It has remarkable strengths for common etching, but requires peculiar management for photoglyphic engraving; and as the success of that mode of engraving chiefly turns upon this point, it should be well attended to.

"Water dissolves an extraordinary quantity of perchloride of iron, sometimes evolving much heat during the solution. I find that the following is a convenient way of proceeding:—

"A bottle (No. 1) is filled with a saturated solution of perchloride of iron in water.

"A bottle (No. 2) with a mixture, consisting of five or six parts of the saturated solution and one part of water.

"And a bottle (No. 3) with a weaker liquid, consisting of equal parts of water and the saturated solution. Before attempting an engraving of importance, it is almost essential to make preliminary trials, in order to ascertain that these liquids are of the proper strengths. These trials I shall therefore now proceed to point out. I have already explained how the photographic image is made on the surface of the gelatine, and covered with a thin layer of powdered copal or resin, which is then melted by holding the plate over a lamp. When the plate has become perfectly cold, it is ready for the etching process, which is performed as follows:—A small quantity of the solution in bottle No. 2, viz. that consisting of five or six parts of the saturated solution to one of water, is poured upon the plate, and spread with a camel-hair brush evenly all over it. It is not necessary to make a wall of wax around the plate, because the quantity of liquid employed is so small that it has no tendency to run off the plate. The liquid penetrates the gelatine wherever the light has not acted on it, but it refuses to penetrate those parts upon which the light has sufficiently acted. It is upon this remarkable fact that the art of photoglyphic engraving is mainly founded. In about a minute the etching is seen to begin, which is known by the parts etched turning dark brown or black, and then it spreads over the whole plate—the details of the picture appearing with great rapidity in every quarter of it. It is not desirable that this rapidity should be too great, for, in that case, it is necessary to stop the process before the etching has acquired sufficient depth (which requires an action of some minutes' duration). If, therefore, the etching, on trial, is found to proceed too rapidly the strength of the liquid in bottle No. 2 must be altered (by adding some of the saturated solution to it before it is employed for another engraving); but if, on the contrary, the etching fails to occur after the lapse of some minutes, or if it begins, but proceeds too slowly, this is a sign that the liquid in bottle No. 2 is too strong, and too nearly approaching saturation. To correct this, a little water must be added to it before it is employed for another engraving. But, in doing this, the operator must take notice, that a very minute quantity of water added often makes a great difference, and causes the liquid to etch very rapidly. He will therefore be careful in adding water, not to do so too freely. When the proper strength of the solution in bottle No. 2 has thus been adjusted, which generally requires three or four experimental trials, it can be employed with security. Supposing, then, that it has been ascertained to be of the right strength, the etching is commenced, as above mentioned, and proceeds till all the details of the picture have been visible, and present a satisfactory appearance to the eye of the operator, which generally occurs in two or three minutes; the operator stirring the liquid all the time with a camel-hair brush, and thus slightly rubbing the surface of the gelatine, which has a good effect. When it seems likely that the etching will improve no further, it must be stopped. This is done by wiping off the liquid with cotton wool, and then rapidly pouring a stream of cold water over the plate, which carries off all the remainder of it. The plate is then wiped with a clean linen cloth, and then rubbed with soft whiting and water to remove the gelatine. The etching is then found to be completed.

PHOTOGRAPHY. (From photo, light; graph, a writing or a description.) The art
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of producing pictures by the agency of sunshine, acting upon chemically prepared papers. The name appears unfortunate, since we are persuaded that it is not Light—that is, the luminous principle of the sunshine, which effects the chemical change, but a peculiar principle or power which is associated with light in the sunbeam. In the metaphysical refinements of our modern philosophy, which endeavors to refer every physical phenomenon to some peculiar mode of motion, we are apt to lose sight of the stern facts, which, in spite of the enormous amount of talent which has been brought to bear on the whole series of undulatory hypotheses, still stand out as irreconcilable with any of these views. If light is motion, and shadow degrees of repose, it remains unexplained how the most intense motion, yellow light, not only produces no chemical change, but actually prevents it; or how the deep shadow of the non-luminous rays produces the most active chemical decomposition. M. Niepce, in 1827, called his interesting discovery Heliography, or sun-writing. This name, as involving no hypothesis, was an exceedingly happy one, and it is to be regretted that it was not adopted.

In this dictionary it is our purpose only to deal with the chief principles involved in this very interesting art, and to give brief descriptions of some of the more remarkable and interesting of the processes which have been introduced. There are certain chemical compounds, and especially some of the salts of silver, which are rapidly decomposed by the influence of the sunshine, and even, though more slowly, by ordinary daylight, or powerful artificial light. As the extent to which the decomposition is carried on depends upon the intensity of radiation proceeding from the object, or passing through it, accordingly as we are employing the reflected or the transmitted rays, it will be obvious that we shall obtain very different shades of darkening, and thus the photograph will represent in a very refined manner all those details which are rendered visible to the eye by light and shadow.

There are two methods by which photographs can be taken: the first and simplest is by super-position; but this is applicable only to the copying of engravings of such botanical specimens as can be spread out upon paper, and objects which are entirely or in part transparent. The other method is by throwing upon the prepared paper the image obtained by the use of a lens fitted into a dark box—the camera obscura.

To carry out either of these methods, certain sensitive surfaces must be produced; these, therefore, claim our first attention. —The artist requires

1. Nitrate of silver.
2. Ammonia nitrate of silver.
3. Chloride of silver.
4. Iodide of silver.
5. Bromide of silver.

Those five chemical compounds may be regarded as the agents most essential in the preparation of photographic surfaces.

1. Nitrate of Silver. The crystallized salt should, if possible, always be procured. The fused nitrate, which is sold in cylindrical sticks, is more liable to contamination, and the paper in which each stick of two drachms is wrapped being weighed with the silver, renders it less economical. A preparation is sometimes sold for nitrate of silver, at from 6d. to 9d., the ounce less than the ordinary price, which may induce the unwary to purchase it. This reduction of price is effected by fusing with the salt of silver a proportion of some cuprous salt, generally the nitrate, or nitrate of potash. This fraud is readily detected by observing if the salt becomes moist on exposure to the air—a very small admixture of copper rendering the nitrate of silver deliquescent. The evils to the photographer are, want of sensibility upon exposure, and the perishability (even in the dark) of the finished drawing.

The most simple kind of photographic paper which is prepared, is that washed with the nitrate of silver only; and for many purposes it answers remarkably well, particularly for copying lace or feathers; and it has this advantage over every other kind, that it is perfectly fixed by well soaking in pure warm water.

The best proportions in which this salt can be used are 60 grains of it dissolved in a fluid ounce of water. Care must be taken to apply it equally, with a quick but steady motion, over every part of the paper. It will be found the best practice to pin the sheet by its four corners to a flat board, and then, holding it with the left hand a little inclined, to sweep the brush from the upper outside corner, over the whole of the sheet, removing it as seldom as possible.

The nitrated paper not being very sensitive to luminous agency, it is desirable to increase its power. This may be done to some extent by simple methods. By soaking the paper in a solution of sinnglass or parchment size, or by rubbing it over with the white of egg, and drying it prior to the application of the sensitive wash, it will be found to blacken much more readily, and assume different tones of color, which may be varied at the taste of the operator.

By dissolving the nitrate of silver in common rectified spirits of wine instead of water, we produce a tolerably sensitive nitrated paper, which darkens to a very beautiful chocolate
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brown; but this wash must not be used on any sheets prepared with isinglass, parchment, or albumen, as these substances are coagulated by alcohol.

2. Ammonia Nitrate of Silver. Liquid ammonia is to be dropped carefully into nitrate of silver; a dark oxide of silver is thrown down; if the ammonia liquor is added in excess, this precipitate is redissolved, and we obtain a perfectly colorless solution. Paper washed with this solution is more sensitive than that prepared with the ordinary nitrate.

3. Chloride of Silver. This salt is obtained most readily by pouring a solution of common salt, chloride of sodium, into a solution of nitrate of silver. It then falls as a pure white precipitate, which rapidly changes color even in diffused daylight.

Chloridated papers, as they are termed, are formed by producing a chloride of silver on their surface, by washing the paper with the solution of chloride of sodium, or any other chloride, and when the paper is dry, with the silver solution.

It is a very instructive practice to prepare small quantities of solutions of common salt and nitrate of silver of different strengths, to cover slips of paper with them in various ways, and then to expose them all to the same radiations. A curious variety in the degrees of sensibility, and in the intensity of color, will be detected, showing the importance of a very close attention to proportions, and also to the mode of manipulating.

A knowledge of these preliminary but important points having been obtained, the preparation of the paper should be proceeded with; and the following method is recommended:

Taking some flat deal boards, perfectly clean, pin upon them, by their four corners, the paper to be prepared; observing the two sides of the paper, with the iodide of silver to receive the preparation which presents the hardest and most uniform surface. Then, dipping a sponge brush into the solution of chloride of sodium, a sufficient quantity is taken up by it to moisten the surface of the paper without any hard rubbing; and this is to be applied with great regularity. The papers being "salted," are allowed to dry. A great number of these may be prepared at a time, and kept in a portfolio for use. To render these sensitive, the papers being pinned on the boards, or carefully laid upon folds of white blotting-paper, are to be washed over with the nitrate of silver, applied by means of a camel's-hair pencil, observing the instructions previously given as to the method of moving the brush upon the paper. After the first wash is applied, the paper is to be dried, and then subjected to a second application of the silver solution. Thus prepared, it will be sufficiently sensitive for all purposes of copying by application.

The most sensitive paper.—Chloride of sodium, 30 grains to an ounce of water; nitrate of silver, 120 grains to an ounce of distilled water.

The paper is first soaked in the saline solution, and after being carefully wiped with linen, or pressed between folds of blotting-paper and dried, it is to be washed twice with the solution of silver, drying it by a warm fire between each washing. This paper is very liable to become brown in the dark. Although images may be obtained in the camera obscura on this paper by about half an hour's exposure, they are never very distinct, and may be regarded as rather curious than useful.

Less sensitive paper for copies of engravings or botanical specimens.—Chloride of sodium, 25 grains to an ounce of water; nitrate of silver, 90 grains to an ounce of distilled water.

Common sensitive paper, for copying lace-work, feathers, &c.—Chloride of sodium, 50 grains to an ounce of water; nitrate of silver, 60 grains to an ounce of distilled water.

This paper keeps tolerably well, and, if carefully prepared, may always be depended upon for darkening equally.

4. Iodide of Silver. This salt was employed very early by Talbot, (see Calotype, vol. 1,) Herschel, and others, and it enters as the principal agent into Mr. Talbot's calotype paper. Paper is washed with a solution of the iodide of potassium, and then with nitrate of silver. By this means papers may be prepared which are exquisitely sensitive to luminous influence, provided the right proportions are hit; but, at the same time, nothing can be more insensible to the same agency than the pure iodide of silver. A singular difference in precipitates to all appearance the same led to the belief that more than one definite compound of iodine and silver existed; but it is now proved that pure iodide of silver will not change color in the sunshine, and that the quantity of nitrate of silver in excess regulates the degree of sensibility. Experiment has proved that the blackening of one variety of iodated paper, and the preservation of another, depend on the simple admixture of a very minute excess of the nitrate of silver. The papers prepared with the iodide of silver have all the peculiarities of those prepared with the chloride, and although, in some instances, they seem to exhibit a much higher order of sensitiveness, they cannot be recommended for general purposes with that confidence which experience has given to the chloride.

5. Bromide of Silver. In many of the works on chemistry, it is stated that the chloride is the most sensitive to light of all the salts of silver; and, when they are exposed in a perfectly formed and pure state to solar influence, it will be found that this is nearly correct. Modern discovery has, however, shown that these salts may exist in peculiar conditions, in which the affinities are so delicately balanced as to be disturbed by the faintest
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gleam; and it is singular that, as it regards the chloride, iodide, and bromide of silver, when in this condition, the order of sensibility is reversed, and the most decided action is evident on the bromide before the eye can detect any change in the chloride.

To prepare a highly sensitive paper of this kind, select some sheets of very superior glazed paper, and wash it on one side only with bromide of potassium—40 grains to 1 ounce of distilled water, over which, when dry, pass a solution of 100 grains of nitrate of silver in the same quantity of water. The paper must be dried as quickly as possible without exposing it to too much heat; then again washed with the silver solution, and dried in the dark. Such are the preparations of an ordinary kind, with which the photographer will proceed to work.

The most simple method of obtaining sun-pictures, is that of placing the objects to be copied on a piece of prepared paper, pressing them close by a piece of glass, and exposing the arrangement to sunshine: all the parts exposed darken, while those covered are protected from change, the resulting picture being white upon a dark ground.

For the multiplication of photographic drawings, it is necessary to be provided with a frame and glass, called a copying frame. The glass must be of such thickness as to resist considerable pressure, and it should be selected as colorless as possible, great care being taken to avoid such as have a tint of yellow or red, these colors preventing the permeation of the most efficient rays; fig. 559 represents the frame, showing the back, with its adjustments for securing the close contact of the paper with every part of the object to be copied.

Having placed the frame face downward, carefully lay out on the glass the object to be copied, on which place the photographic paper very smoothly. Having covered this with the cushion, which may be either of flannel or velvet, fix the back, and adjust it by the bar, until every part of the object and paper is in the closest possible contact; then turn up the frame and expose to sunshine.

It should be here stated, once for all, that such pictures, however obtained, are called negative photographs; and those which have their lights and shadows correct as in nature—dark upon a light ground—are positive photographs. The mode of effecting the production of a positive is: having, by fixing, given permanence to the negative picture, it is placed, face down, on another piece of sensitive paper, when all the parts which are white on the first, admitting light freely, cause a dark impression to be made on the second, and the resulting image is correct in its lights and shadows, and also as it regards right and left.

For obtaining pictures of external nature, the camera obscura of Baptista Porta is employed.

The figures (figs. 560, 561, 562) represent a perfect arrangement, and, at the same time, one which is not essentially expensive. Its conveniences are those of folding, (fig. 562,) and thus packing into a very small compass, for the convenience of travellers.

Fig. 560 exhibits the instrument complete. Fig. 561 shows the screen in which the sensitive paper is placed, the shutter being up and the frame open that its construction may be seen.
PHOTOGRAPHY.

Camera obscuras of a more elaborate character are constructed, and many of exceeding ingenuity, which give every facility for carrying on the manipulations for the collodion process, to be presently described, out of doors. The preceding is a camera obscura of this kind, manufactured by Mr. John Joseph Griffin, of Bunhill Row.

This is really Mr. Scott Archer's camera obscura improved upon. Fig. 563 is a section of the instrument, and fig. 564 its external form. With a view to its portability, it is constructed so as to serve as a packing-case for all the apparatus required. a is a sliding door which supports the lens, b. c, e, are side openings fitted with cloth sleeves to admit the operator's arms. d is a hinged door at the back of the camera, which can be supported like a table by the hook e. f is the opening for looking into the camera during an operation. This opening is closed when necessary by the door g, which can be opened by the hand passed into the camera through the sleeves c. The yellow glass window which admits light into the camera during an operation is under the door h. i is the sliding frame for holding the focusing glass, or the frame with the prepared glass, either of which is fastened to the sliding frame by the check k. The frame slides along the rod l, and can be fitted to the proper focus by means of the step m. n is the gutta-percha washing-tray. o is an opening in the bottom of the instrument near the door, to admit the well p, and which is closed when the well is removed by the door. The well is divided into two cells, one of which contains the focusing glass, and the other the glass trough, each in a frame adapted to the sliding frame l. On each side of the sliding door that supports the lens a, there is within the camera a small hinged table, r, supported by a bracket, s. These two tables serve to sup-
port the bottles that contain the solutions necessary to be applied to the glass plate after its exposure to the lens.

For supporting any of these camera obscuras, tripod stands are employed; these are now made in an exceedingly convenient form, being light, at the same time that they are sufficiently firm to secure the instrument from any motion during the operation of taking a picture.

The true photographic artist, however, will not be content with a camera obscura of this or any other kind. He will provide himself with a tent, in which he may be able to prepare his plates, and subsequently to develop and to fix his pictures. Many kinds of tent have been brought forward, but we have not seen any one which unites so perfectly all that can be desired, within a limited space, and which shall have the great recommendation of lightness. Fig. 565 represents Smartt's new photographic tent, which appears to meet nearly all the conditions required.

In this tent an endeavor has been made to obviate many of the inconveniences complained of, especially as to working space, firmness, simplicity, and portability. Usually, in the various forms of tent, the upper part, where space is most required, is the most contracted, while at the lower part, where it is of little importance, a great amount of room is provided.

Smartt's tent, made by Murray & Heath, is rectangular in form, is 6 feet high in the clear, and 3 feet square, affording table space equal to 36 inches by 18 inches, and ample room for the operator to manipulate with perfect ease and convenience. The chief feature in its construction is the peculiarity of its framework, which constitutes, when erected, a system of triangles, so disposed as to strengthen and support each other; it thus combines the two important qualities of lightness and rigidity. The table is made to fold up when not in use; and in place of the ordinary dish for developing, a very efficient and portable tray is provided, made of india-rubber cloth, having its two sides fixed and rigid and its two
PHOTOGRAPHY.

ends movable: it thus folds up into a space but little larger than one of its sides. The working space of the table is economized thus:—a portion of it is occupied by the tray just described; the silver-bath (which is one of Murray & Heath's new glass baths, with glass water-tight top) is suspended from the front of the table, and rests upon a portion of the framework of the tent; a contrivance is devised for disposing of the plate-slide of the camera, in order to reserve the space it would require if placed on the table. The bath and plate-holder, in their places as described, are shown in the wood-cut. This arrangement leaves ample space on the table for manipulating the largest-sized plates. The entire weight of the tent is 20 lbs., and it is easily erected or taken down by one person.

The collodion puffer, the plate-developing holder, the developing cups, and the water-bottle, (the latter is suspended over the tray as in the wood-cut,) have all special points in construction.

The object of the inventor has been completely realized, the operator being insured the means of working the wet-collodion process in the open air with ease, comfort, and convenience. Hitherto this has not been possible, in consequence of the great weight and bulk of the contrivances used, and to which may be traced the existence of the many expedients for retaining, more or less, the sensitiveness of the prepared plate.

The object of the inventor has been to make a tent which shall be so efficient as to ensure to the operator the means of working the wet collodion process in the open air with ease, comfort, and convenience.

The processes of most importance may be divided as follows:—

1. The copying process, already described.
2. The Daguerreotype, the earliest method successfully employed for obtaining pictures by means of the camera obscura. See DAGUERREOTYPE.
3. The Calotype of Mr. H. Fox Talbot, in which the sensibility of the iodide of silver is exalted by the agency of that peculiar organic compound, gallic acid. See CALOTYPE.
4. The Collodion process, which must be succinctly described hereafter.

In addition to the ordinary form of the calotype process devised by Mr. Fox Talbot, and of which an account has been given under the proper head, the Wax-paper process demands some attention. The following directions are those given by Mr. Wm. Crookes, who has devoted much attention to, and who has been eminently successful with, the wax-paper:—

The first operation to be performed is to make a slight pencil-mark on that side of the paper which is to receive the sensitive coating. If a sheet of Canon's paper be examined in a good light, one of the sides will be found to present a finely reticulated appearance, while the other will be perfectly smooth; this latter is the one that should be marked. Fifty or a hundred sheets may be marked at once, by holding a pile of them firmly by one end, and then bending the pocket round, until the loose ends separate from another like a fan; generally all the sheets lie in the same direction, therefore it is only necessary to ascertain that the smooth side of one of them is uppermost, and then draw a pencil once or twice along the exposed edges.

The paper has now to be saturated with white wax. The wax is to be made perfectly liquid, and then the sheets of paper, taken up singly and held by one end, are gradually lowered on to the fluid. As soon as the wax is absorbed, which takes place almost directly, they are to be lifted up with rather a quick movement, held by one corner, and allowed to drain until the wax, ceasing to run off, congeals on the surface. When the sheets are first taken up for this operation, they should be briefly examined, and such as show the water-mark, contain any black spots, or have any thing unusual about their appearance, should be rejected.

The paper in this stage will contain far more wax than necessary; the excess may be removed by placing the sheets singly between blotting-paper, and ironing them; but this is wasteful, and the loss may be avoided by placing on each side of the waxed sheet two or three sheets of unwaxed photographic paper, and then ironing the whole between blotting-paper; there will generally be enough wax on the centre sheet to saturate fully those next to it on each side, and partially, if not entirely, the others. Those that are imperfectly waxed may be made the outer sheets of the succeeding set. Finally, each sheet must be separately ironed between blotting-paper, until the glistening patches of wax are absorbed.

It is of the utmost consequence that the temperature of the iron should not exceed that of boiling water. Before using, always dip it into water until the hissing entirely ceases. This is one of the most important points in the whole process, but one which it is very difficult to make beginners properly appreciate. The disadvantages of having too hot an iron are not apparent until an alter stage, while the saving of time and trouble is a great temptation to beginners.

A well-waxed sheet of paper, when viewed by obliquely reflected light, ought to present a perfectly uniform glazed appearance on one side, while the other should be rather duller; there must be no shining patches on any part of the surface, nor should any irregularities be observed on examining the paper with a black ground placed behind; seen by transmit-
PHOTOGRAPHY.

925
ted light, it will appear opalescent, but there should be no approach to a granular structure. The color of a pile of waxed sheets is slightly bluish.

The paper, having undergone this preparatory operation, is ready for iodizing; this is effected by completely immersing it in an aqueous solution of an alkaline iodide, either pure or mixed with some analogous salt.

Bromide of potassium is sometimes added, and with much advantage in many cases, to the iodizing bath. The addition of a chloride has been found to produce a somewhat similar effect to that of a bromide, but in a less marked degree. No particular advantage, however, can be traced to it.

The best results are obtained when the iodide and bromide are mixed in the proportion of their atomic weights, the strength being as follows:—

<table>
<thead>
<tr>
<th>Solution</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodide of potassium</td>
<td>528.5 grains.</td>
</tr>
<tr>
<td>Bromide of potassium</td>
<td>417.5 grains.</td>
</tr>
<tr>
<td>Distilled water</td>
<td>40 ounces.</td>
</tr>
</tbody>
</table>

When the two salts have dissolved in the water, the mixture should be filtered; the bath will then be fit for use.

At first a slight difficulty will be felt in immersing the waxed sheets in the liquid without enclosing air-bubbles, the greasy nature of the surface causing the solution to run off. The best way is to hold the paper by one end, and gradually to bring it down on to the liquid, commencing at the other end; the paper ought not to slant toward the surface of the bath, or there will be danger of enclosing air-bubbles; but while it is being laid down, the part out of the liquid should be kept as nearly as possible perpendicular to the surface of the liquid; any curling up of the sheet when first laid down may be prevented by breathing on it gently. In about ten minutes the sheet ought to be lifted up by one corner, and turned in the same manner; a slight agitation of the dish will then throw the liquid entirely over that sheet, and another can be treated in like manner.

These sheets must remain soaking in this bath for about three hours; several times during that interval (and especially if there be many sheets in the same bath) they ought to be moved about and turned over singly, to allow of the liquid penetrating between them, and coming perfectly in contact with every part of the surface. After they have soaked for a sufficient time, the sheets should be taken out and hung up to dry; this is conveniently effected by stretching a string across the room, and hooking the papers on to this by means of a pin bent into the shape of the letter S. After a sheet has been hung up for a few minutes, a piece of blotting-paper, about one inch square, should be stuck to the bottom corner to absorb the drop, and prevent its drying on the sheet, or it would cause a stain in the picture.

While the sheets are drying, they should be looked at occasionally, and the way in which the liquid on the surface dries noticed; if it collect in drops all over the surface, it is a sign that the sheets have not been sufficiently acted on by the iodizing bath, owing to their having been removed from the latter too soon. The sheets will usually during drying assume a dirty pink appearance, owing probably to the liberation of iodine by ozone in the air, and its subsequent combination with the starch and wax in the paper. This is by no means a bad sign. If the color be at all uniform; but if it appear in patches and spots, it shows that there has been some irregular absorption of the wax, or defect in the iodizing, and it will be as well to reject sheets so marked.

As soon as the sheets are quite dry, they can be put aside in a box for use at a future time. There is a great deal of uncertainty as regards the length of time the sheets may be kept in this state without spoiling. Mr. Crookes speaks from experience as to there being no sensible deterioration after a lapse of ten months.

Up to this stage, it is immaterial whether the operations have been performed by daylight or not; but the subsequent treatment, until the fixing of the picture, must be done by yellow light.

The next step consists in rendering the iodized paper sensitive to light. Although, when extreme care is taken in this operation, it is hardly of any consequence when this is performed; yet, in practice, it will not be found convenient to expose the paper earlier than about a fortnight before its being required for use. The materials for the exciting bath are nitrate of silver, glacial acetic acid, and water.

The following bath is recommended:—

<table>
<thead>
<tr>
<th>Solution</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate of silver</td>
<td>300 grains.</td>
</tr>
<tr>
<td>Glacial acetic acid</td>
<td>2 drachms.</td>
</tr>
<tr>
<td>Distilled water</td>
<td>20 ounces.</td>
</tr>
</tbody>
</table>

The nitrate of silver and acetic acid are to be added to the water, and when dissolved, filtered into a clean dish, taking care that the bottom of the dish be flat, and that the liquid cover it to the depth of at least half an inch all over; by the side of this, two similar dishes must be placed, each containing distilled water.

A sheet of iodized paper is to be taken by one end, and gradually lowered, the marked
PHOTOGRAPHY.

side downward, on to the exciting solution, taking care that no liquid gets on to the back, and no air-bubbles are enclosed.

It will be necessary for the sheet to remain on this bath from five to ten minutes; but it can generally be known when the operation is completed by the change in appearance, the pink color entirely disappearing, and the sheet assuming a pure homogeneous straw color. When this is the case, one corner of it must be raised up by the platinum spatula, lifted out of the dish with rather a quick movement, allowed to drain for about half a minute, and then floated on the surface of the water in the second dish, while another iodized sheet is placed on the nitrate of silver solution; when this has remained on for a sufficient time, it must be in like manner transferred to the dish of distilled water, having removed the previous sheet to the next dish.

A third iodized sheet can now be excited, and when this is completed, the one first excited must be rubbed perfectly dry between folds of clean blotting-paper, wrapped up in clean paper, and preserved in a portfolio until required for use; and the others can be transferred a dish forward, as before, taking care that each sheet be washed twice in distilled water, and that at every fourth sheet the dishes of washing water be emptied and replenished with clean distilled water; this water should not be thrown away, but preserved in a bottle for a subsequent operation.

The above quantity of the exciting bath will be found quite enough to excite about fifty sheets of the size here employed, or 3,000 square inches of paper.

Of course these sensitive sheets must be kept in perfect darkness. Generally, sufficient attention is not paid to this point. It should be borne in mind, that an amount of white light, quite harmless if the paper were only exposed to its action for a few minutes, will infallibly destroy it if it be allowed to have access to it for any length of time; therefore, the longer the sheets are required to be kept, the more carefully must the light, even from gas, be excluded; they must likewise be kept away from any fumes or vapor.

Experience alone can tell the proper time to expose the sensitive paper to the action of light, in order to obtain the best effects. However, it will be useful to remember, that it is almost always possible, however short the time of exposure, to obtain some trace of effect by prolonged development. Varying the time of exposure, within certain limits, makes very little difference on the finished picture; its principal effect being to shorten or prolong the time of development.

Unless the exposure to light has been extremely long, (much longer than can take place under the circumstances we are contemplating,) nothing will be visible on the sheet after its removal from the instrument more than there was previous to exposure; the action of the light merely producing a latent impression, which requires to be developed to render it visible.

The developing solution in nearly every case consists of an aqueous solution of gallic acid, with the addition, more or less, of a solution of nitrate of silver.

An improvement on the ordinary method of developing with gallic acid, formed the subject of a communication from Mr. Crookes to the Philosophical Magazine for March, 1855, who recommends the employment of a strong alcoholic solution of gallic acid, to be diluted with water when required for use, as being more economical both of time and trouble than the preparation of a great quantity of an aqueous solution for each operation.

The solution is thus made: Put two ounces of crystallized gallic acid into a dry flask with a narrow neck; over this pour six ounces of good alcohol, (60° over proof), and place the flask in hot water until the acid is dissolved, or nearly so. This will not take long, especially if it be well shaken once or twice. Allow it to cool, then add half a dram of glacial acetic acid, and filter the whole into a stoppered bottle.

The developing solution for one set of sheets, or 180 square inches, is prepared by mixing together ten ounces of the water that has been previously used for washing the excited papers, and 4 drachms of the exhausted exciting bath; the mixture is then filtered into a perfectly clean dish, and half a dram of the above alcoholic solution of gallic acid poured into it. The dish must be shaken about until the greasy appearance is quite gone from the surface; and then the sheets of paper may be laid down on the solution in the ordinary manner with the marked side downward, taking particular care that none of the solution gets on the back of the paper, or it will cause a stain. Should this happen, either dry it with blotting-paper, or immerse the sheet entirely in the liquid.

If the paper has been exposed to a moderate light, the picture will begin to appear within five minutes of its being laid on the solution, and will be finished in a few hours. It may, however, sometimes be requisite, if the light has been feeble, to prolong the development for a few more minutes. If the dish be perfectly clean, the developing solution will remain active for the whole of this time, and when used only for a few hours, will be quite clear and colorless, or with the faintest tinge of brown; a darker appearance indicates the presence of dirt. The progress of the development may be watched, by gently raising one corner with the platinum spatula, and lifting the sheet up by the fingers. This should not be done too often, as there is always a risk of producing stains on the surface of the picture.
PHOTOGRAPHY.

As soon as the picture is judged to be sufficiently intense, it must be removed from the gallo-nitrate, and laid on a dish of water, (not necessarily distilled.) In this state it may remain until the final operation of fixing, which need not be performed immediately, if inconvenient. After being washed once or twice, and dried between clean blotting-paper, the picture will remain unharmed for weeks, if kept in a dark place.

Some general remarks on the fixing processes will be found toward the end of this article.

THE COLLODION PROCESS.

The difficulty with which we are met in any attempt to describe this photographic process is, that it is almost hopeless to find two photographers who adopt precisely the same order of manipulation; and books almost without number have been published, each one recommending some special system.

By general consent the discovery of the collodion process, as now employed, is given to the late Mr. Scott Archer. It will, therefore, be considered quite sufficient to give the details of his process, which has really been but little improved on since its first introduction.

To prepare the collodion.—Thirty grains of gum-cotton should be taken and placed in 18 fluid ounces of rectified sulphuric ether, and then 2 ounces of alcohol should be added, making thus one imperial pint of the solution. The cotton, if properly made, will dissolve entirely; but any small fibre which may be floating about should be allowed to deposit, and the clear solution poured off.

To iodize the collodion.—Prepare a saturated solution of iodide of potassium in alcohol —say one ounce —and add to it as much iodide of silver, recently precipitated and well washed, as it will take up: this solution is to be added to the collodion, the quantity depending on the proportion of alcohol which has been used in the preparation of the collodion.

Coating the plate.—A plate of perfectly smooth glass, free from air-bubble or striae, should be cleaned very perfectly with a few drops of ammonia on cotton, and then wiped in a very clean cotton cloth.

The plate must be held by the left hand perfectly horizontal, and then with the right a sufficient quantity of iodized collodion should be poured into the centre, so as to diffuse itself equally over the surface. This should be done coolly and steadily, allowing it to flow to each corner in succession, taking care that the edges are well covered; then gently tilt the plate, that the superfluous fluid may return to the bottle from the opposite corner to that by which the plate is held. At this moment the plate should be brought into a vertical position, when the diagonal lines caused by the fluid running to the corner will fall one into the other, and give a clear flat surface. To do this neatly and effectually, some little practice is necessary, as in most things; but the operator should by no means hurry the operation, but do it systematically, at the same time not being longer over it than is actually necessary, for collodion, being an ethereal compound, evaporates rapidly. Many operators waste their collodion by imagining it is necessary to perform this operation in great haste; but such is not the case, for an even coating can seldom be obtained if the fluid is poured on and off again too rapidly; it is better to do it steadily, and submit to a small loss from evaporation. If the collodion becomes too thin, thin it with the addition of a little fresh and good ether.

Exciting the plate.—Previous to the last operation it is necessary to have the bath ready, which is made as follows:—

<table>
<thead>
<tr>
<th>Nitrate of silver</th>
<th>30 grains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled water</td>
<td>1 ounce</td>
</tr>
</tbody>
</table>

Dissolve and filter.

The quantity of this fluid necessary to be made must depend upon the form of trough to be used, whether horizontal or vertical, and also upon the size of the plate. With the vertical trough a glass dipper is provided, upon which the plate rests, preventing the necessity of any handle or the fingers going into the liquid. If, however, the glass used is a little larger than required, this is not necessary. Having thus obtained one or other of these two, and filtered the liquid previously, the plate, free from any particle of dust, &c., is to be immersed steadily and without hesitation; for if a pause should be made in any part, a line is sure to be formed, which will print in a subsequent part of the process.

The plate being immersed in the solution must be kept there a sufficient time for the liquid to act freely upon the surface, particularly if a negative picture is to be obtained. As a general rule, it will take about two minutes, but this will vary with the temperature of the air at the time of operation, and the condition of the collodion. In cold weather, or indeed, any thing below 50° F., the bath should be placed in a warm situation, or a proper decomposition is not obtained under a very long time. Above 60° the plate will be certain to have obtained its maximum of sensibility by two minutes’ immersion, but below this temperature it is better to give a little extra time.
PHOTOGRAPHY.

To facilitate the action, let the temperature be what it may, the plate must be lifted out of the liquid two or three times, which also assists in getting rid of the ether from the surface, for without this is thoroughly done, a uniform coating cannot be obtained; but on no account should it be removed until the plate has been immersed about half a minute, as marks are apt to be produced if removed sooner.

The plate is now ready to receive its impression in the camera obscura. This having been done, the picture is to be developed.

The development of image.—To effect this, the plate must be taken again into the dark room, and with care removed from the slide to the levelling stand.

It will be well to caution the operator respecting the removal of the plate. Glass, as before observed, is a bad conductor of heat; therefore, if in taking it out, we allow it to rest on the fingers at any one spot too long, that portion will be warmed through to the face, and as this is not done until the developing solution is ready to go over, the action will be more energetic at those parts than at others, and consequently destroy the evenness of the picture. We should, therefore, handle the plate with care, as if it already possessed too much heat to be comfortable to the fingers, and that we must therefore get it on the stand as soon as possible.

Having then got it there, we must next cover the face with the developing solution.

This should be made as follows:—

<table>
<thead>
<tr>
<th>Pyrogallic acid</th>
<th>Glacial acetic acid</th>
<th>Distilled water</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 grains.</td>
<td>40 minims.</td>
<td>10 ounces.</td>
</tr>
</tbody>
</table>

Dissolve and filter.

Mr. Delamotte employs

<table>
<thead>
<tr>
<th>Pyrogallic acid</th>
<th>Glacial acetic acid</th>
<th>Distilled water</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 grains.</td>
<td>2 drachms.</td>
<td>3 ounces.</td>
</tr>
</tbody>
</table>

Now, in developing a plate, the quantity of liquid taken must be in proportion to its size. A plate measuring 5 inches by 4 will require half an ounce; less may be used, but it is at the risk of stains; therefore we would recommend that half an ounce of the above be measured out, into a perfectly clean measure, and to this from 8 to 12 drops of a 50-grain solution of nitrate of silver be added.

Pour this quickly over the surface, taking care not to hold the measure too high, and not to pour all on one spot, but having taken the measure properly in the fingers, begin at one end, and carry the hand forward; immediately blow upon the face of the plate, which has the effect not only of diffusing it over the surface, but causes the solution to combine more equally with the damp surface of the plate: it also has the effect of keeping any deposit that may form in motion, which, if allowed to settle, causes the picture to come out mottled. A piece of white paper may now be held under the plate, to observe the development of the picture: if the light of the room is adapted for viewing it in this manner; well; if not, a light must be held below, but in either case arrangements should be made to view the plate easily whilst under the operation: a successful result depending so much upon obtaining sufficient development without carrying it too far.

As soon as the necessary development has been obtained, the liquor must be poured off, and the surface washed with a little water, which is easily done by holding the plate over a dish, and pouring water on it; taking care, both in this and a subsequent part of the process, to hold the plate horizontally, and not vertically, so as to prevent the coating being torn by the force and weight of water.

Protosulphate of iron, which was first introduced as a photographic agent in 1840 by Robert Hunt, may be employed instead of the pyrogallic acid with much advantage. The beautiful collodion portraits obtained by Mr. Tunny of Edinburgh are all developed by the iron salt. The following are the best proportions:

<table>
<thead>
<tr>
<th>Protosulphate of iron</th>
<th>Acetic acid</th>
<th>Distilled water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ounce.</td>
<td>12 minims.</td>
<td>1 pint.</td>
</tr>
</tbody>
</table>

This is used in the same manner as the former solutions.

Fixing of image.—This is simply the removal of iodide of silver from the surface of the plate, and is effected by pouring over it, after it has been dipped into water, a solution of hyposulphite of soda, made of the strength of 4 ounces to a pint of water. At this point daylight may be admitted into the room, and, indeed, we cannot judge well of its removal without it. We then see by lifting the plate to and fro the iodide gradually dissolve away, and the different parts left more or less transparent, according to the action of light upon them.

It then only remains to thoroughly wash away every trace of the hyposulphite of soda, for should any salt be left, it gradually destroys the picture. The plate should therefore either be immersed with great care in a vessel of clean water; or, what is better, water
POUMBAHO.

Poured gently and carefully over the surface. After this it must be placed upright to dry, or held before a fire.

The fixing processes. The most important part of Photography, and one to which the least attention has been paid, is the process of rendering permanent the beautiful images which have been obtained. Nearly all the fine photographs with which we are now familiar are not permanent. This is deeply to be regretted, especially as there appears to be no necessity for their fading away. In nearly all cases the fading of a photograph may be referred to carelessness, and it is not a little startling, and certainly very annoying, to hear a very large dealer in photographic pictures declare that the finest pictures by the best photographers are the first to fade. This is, no doubt, to be accounted for by the demand which there is for their pictures, leading to a fatal rapidity in the necessary manipulatory details.

There is no necessity for a photograph to fade if kept with ordinary care. It should be at all events as permanent as a sepia drawing. The hyposulphite of soda is the true fixing agent for any of the photographic processes, be they Daguerreotype, calotype, collodion, or the ordinary process for producing positive prints. It should be understood, whichever of the salts of silver are employed, that by the action of the solar rays either oxide of silver or metallic silver is produced, and the unchanged chloride, iodide, or bromide can be dissolved out by the use of the hyposulphite of soda.

The photographic picture on paper, on metal, or on glass, is washed with a strong solution of the hyposulphite of soda, and the silver salt employed combines with it, forming a peculiarly sweet compound, the hyposulphite of silver; this is soluble in water, and hence we have only to remove it by copious ablutions. The usual practice is to place the pictures in trays of water and to change the fluid frequently. In this is the danger, and to it may be traced the fading of nine-tenths of the pictures prepared on paper.

Paper is a mass of linen or cotton fibre; however fine the pulp may be prepared, it is still full of capillary pores, which, by virtue of the force called capillarity, hold with enormous force a large portion of the solid contents of the water. If we make a solution of a known strength of the hyposulphite of soda, and dip a piece of paper into it, it will be found to have lost more of the salt than belongs to the small quantity of water abstracted by the paper. Solid matter in excess has been withdrawn from the solution. So a photographic picture on paper holds with great tenacity one or other of the hyposulphites. By soaking there is of course a certain portion removed, but it is not possible by any system of soaking to remove it all.

The picture is, however, prepared in this manner, and slowly, but surely, under the combined influences of the solar rays and atmospheric moisture, the metallic silver loses color, i. e., the photograph fades.

The only process to be relied on demands that every picture should be treated separately. First, any number may be soaked in water, and the water changed; by this means the excess of the hyposulphite of silver is removed. Then each picture must be taken out and placed upon a slab of porcelain or glass, and being fixed at a small angle, water should be allowed to flow freely over and off it. Beyond this, the operator should be furnished with a piece of soft sponge, and he should maintain for a long time a dabbing motion. By this mechanical means he disturbs the solid matter held in the capillary tubes, and eventually removes it. The labor thus bestowed is rewarded by the production of a permanent picture, not to be secured by any other means.

In this article those processes only which have become of commercial value have been noted. The Carbon process of printing, which promises well, can scarcely be said to be as yet in a perfect state; and for the other curious but less important processes, and for a full examination of the philosophy of the subject, see Hunt's Researches on Light, 2d edition.

PLATINUM, ALLOYS OF. This metal will alloy with iron; the alloy is malleable, and possesses much lustre.

Copper and platinum in certain proportions form a brilliant alloy.

Silver is much hardened by platinum; although platinum is not soluble in nitric acid, it will, when alloyed with silver, dissolve in that acid.

Some other alloys are known, but none of them are employed.

PLUMBAGO, commonly called Black Lead; the name plumbago, and its common one, being derived from the fact of this mineral resembling lead in its external appearance. In this country plumago has been found most abundantly in Cumberland. The mountain at Borrowdale, in which the black lead is mined, is nearly 3,000 feet high, and the entrance to the mine is about 1,000 feet below its summit. This valuable mineral became so common a subject of robbery about a century ago, as to have enriched, it was said, a great many persons living in the neighborhood. Even the guard stationed over it by the proprietors was of little avail against men infuriated with the love of plunder; since in those days a body of miners broke into the mine by main force, and held possession of it for a considerable time.

The treasure was then protected by a building, consisting of four rooms upon the ground floor; and immediately under one of them is the opening, secured by a trap-door, through
which alone workmen could enter the interior of the mountain. In this apartment, called
the dressing-room, the miners change their ordinary clothes for their mining dress. At one
time as much as £100,000 was realized from the Borrowdale mine in a year, the Cumber-
land plumbago selling at 4s. per pound. This mine has not, however, been worked for
many years. The last great discovery, stated to have been about £20,000's worth, has been
hoarded by the proprietors, a small quantity only being sold every year; but it is now gen-
erally understood to be nearly exhausted. Some few years since the Borrowdale Black
Lead Mine was inspected by three experienced miners, but their report was far from en-
couraging; notwithstanding which a new company has been recently (1859) formed to work
this mine.

This plumbago in Borrowdale is found in "nests" in a trap rock, partially decomposed,
which runs through the clay slate. In Glenstrutharrivée in Inverness, it is found in gneiss,
and at Craigman in Ayrshire it occurs in coal beds which have been formed in contact with
trap. In Cornwall plumbago has been discovered in small lumps in the Elvan courses; and
on the northern coast of that country, small pieces are picked out of the clay slate rocks,
where it has been exposed by the wearing down of the cliffs. At Arendal, in Norway, it
occurs with quartz. Plumbago is sometimes formed in considerable quantities in the beds
of blast furnaces, especially at Cleator Moor.

Plumbago occurs in Finland. Large quantities are brought from Ceylon and the East
Indies. Some considerable portions are obtained from the mines of the United States.

Mr. Brodie purifies plumbago by mixing it in coarse powder, in an iron vessel, with
twice its own weight of commercial sulphuric acid, and then per cent. of chloride of pot-
ash, and heats the whole over a water bath until chloric oxide ceases to be evolved. By
this means the compounds of iron, lime, and alumina present, are rendered for the most
part soluble, and the subsequent addition of a little fluoride of sodium to the acid mixture,
will decompose any silicates which may remain, and volatilize the silica present. The mass
is now washed with abundance of water, dried, and heated to redness. This last operation
causes the grains of the plumbago to exfoliate. The mass swells up in a surprising man-
er, and is reduced to a state of very minute division. It is then levigated, and obtained
in a state of great purity, ready to be compressed by the method of Brockedon—T. S. H.

POAKE. A name amongst peltmongers for the collected waste arising in the prepara-
tion of skins; it is used for manure.

PORCELAIN CLAY. (Kaolin.) Nature has, up to a certain point, provided the article
which man requires for the elaboration of the most perfect production of the potter's
art. The clay—China clay, as it is commonly called, or kaolin, as the Chinese have it—is
quarried from amidst the granitic masses of Dartmoor and of Cornwall. We are not at all
satisfied with any of the theories which have been put forward to account for the formation
of porcelain clay. It is commonly stated to be a decomposed granite; this rock, as is well
known, consisting of mica, quartz, and felspar, with sometimes shool and hornblende. The
felspar is supposed to have decomposed; and, as this forms the largest portion of the mass,
the granite is disintegrated by this process. We have, therefore, the mica, quartz, and the
clay, forming together a soft mass, lying but a short distance below the surface, but extend-
ing to a considerable depth. It is quite evident that this stratum is not deposited; had it
been so, the particles constituting the mass would have arranged themselves in obedience
to the law of gravity, towards which there is not the slightest attempt. But we do not know
by what process the decomposition of the solid granite could have been effected to a depth
from the surface of upwards of one hundred feet, and then, as it often does, suddenly to
cease. This, however, is a question into which we cannot at present enter. The largest
quantity of porcelain or China clay is manufactured in Cornwall, especially about St. Austell
and St. Stephens; from which, in 1859, about 60,000 tons were sent away to the potteries,
and for paper-making and bleaching.

A spot being discovered where this substance abounds, the operation is commenced by
removing the vegetable soil and substratum, called by the workmen the overburden, which
varies in depth from about three to ten feet. The lowest part of the ground is then select-
ed, in order to secure an outlet for the water used in washing the clay. The overburden
being removed, the clay is dug up in stages: that is, in successive layers or courses, and
each one being excavated to a greater extent than the one immediately below it, the stages
resemble a flight of irregular stairs. The depth of the china clay pits is various, extending
from twenty feet to fifty feet.

The clay when first raised has the appearance and consistence of mortar; it contains
numerous grains of quartz, which are disseminated throughout in the same manner as in
granite. In some parts the clay is stained of a rusty color, from the presence of veins and
imbedded portions of shorl and quartz; these are called by the workmen weed, cope, and
shell, which are carefully separated. The clay is next conveyed to the floor of the washing
place, and is then ready for the first operation of the process.

A heap of the clay being placed on an inclined platform, on which a little stream of
water falls from the height of about six feet, the workman constantly moves it and turns it
over with a p Gigle and shovel, by which means the whole is gradually carried down into an oblong trench beneath, which is also inclined, and which ends in a covered channel that leads to the catch-pits about to be described. In the trench the grains of quartz are deposited, but the other parts of the clay, in consequence of their greater levity, are carried away in a state of suspension.

This water is conducted into a series of pits, each of which is about eight feet long, four in breadth and in depth, and is lined on the sides and bottom with eut moorstone, laid in a waterproof cement. In these pits the porcelain earth is gradually deposited. In the first pit the grosser particles collect; and being of a mixed nature, are always rejected at the end of each day's work by an opening provided for that purpose at the bottom of the pit. When the water has filled the first pit, it overflows into the second, and in like manner into the third; and in these pits, particularly in the second, a deposit also takes place, which is often preserved, and is called by the workmen mike. The water, still holding in suspension the finer and purer particles of porcelain clay, next overflows into larger pits, called ponds, which are of the same depth as the first pits, but about three times as long and wide. Here the clay is gradually deposited, and the clear superfluous water is from time to time discharged by plug-holes on one side of the pond. This process is continued until, by successive accumulations, the ponds are filled. At this stage the clay is in the state of a thick paste; and to complete the process it only remains to be consolidated by drying, and then it is fit for the market.

This, however, is a tedious operation in our damp climate, and is effected as follows:—The moist clay is removed in hand-barrows into pans, which are constructed like the pits and ponds, but are much larger, being about forty feet long, fifteen wide, and a foot and a half in depth. The above dimensions may not be quite correct, for I did not actually measure the pits; they are, however, very near the truth. When the pans are nearly filled, the clay is levelled, and is then allowed to remain undisturbed until it is nearly dry. The time required for this part of the process must depend in a great measure on the state of the weather and the season of the year, because the pans are exposed to the air. During the winter at least eight months are necessary, whilst during the summer less than half the time is sufficient.

When the clay is in a fit state, it is cut into oblong masses, and carried to the drying house—a oblong shed, the sides of which are open wooden frames, constructed in the usual way for keeping off the rain, but admitting the free passage of the air. The clay thus dried is next scraped perfectly clean, and is then packed up into casks, and carried to one of the adjacent ports, to be shipped for the potteries.

The porcelain earth thus prepared is of a beautiful and uniform whiteness, and is perfectly smooth and soft to the touch.—Dr. Bosse's Geology of Cornwall.

The works at Lee Moor, on the borders of Dartmoor, being, however, far more complete, we have selected them as the best for our description. See fig. 568.

Here we see a quarry of this decomposed granite, shining white in the sunshine, and at the bottom of this quarry are numerous workmen employed in filling trucks placed upon a
POTASH, NITRATE OF.

This native material is now carried off to a house, distinguished by the powerful water-wheel which revolves on one side of it, and here it undergoes its first process in manufacture. The trucks are lifted, and the contents discharged into a hopper, from which the clay falls into inclined troughs, through which a strong current of water passes, and the clay is separated from the large particles of quartz and mica, these being discharged over a grating, through which flows the water charged with the clay and the finer matter, the coarser portion sliding off the grating, and falling in a heap outside the building. The water contains not only the pure clay, but the finer particles of silica, mica, silt, or of any other matters which may be mixed with the mass. To separate these from the clay, very complete arrangements are made. Large and deep stone tanks receive the water as it comes from the mill; in these the heavier particles settle; and when each tank becomes full, the mica, &c., is discharged through openings in the bottom, into trucks placed to receive it on a railway, and this, the refuse material of the clay works elsewhere, is here preserved for other uses, to be by-and-by described. The water, charged with its clay, now flows slowly and quietly through a great length of stone channel, and during its progress nearly all the micaceous and other particles subside; the water eventually flowing into very large pits, in which the clay is allowed slowly to deposit. The water enters in a thin sheet at one end, and gradually diffuses itself over the large area. The clay, in an impalpable powder, falls down, and perfectly clear water passes away at the other end. From the clay tanks marked and in the plan, the semi-fluid clay is pumped into the clay-pans, beneath which there circulate hot-water pipes, and in these the clay is finally dried. When a thickness of about eighteen inches is obtained, evaporation is promoted by the gradual artificial temperature produced by the water pipes. After a little time, the clay is sufficiently hard to be cut out, and subjected to its final drying. The clay is cut out in squares of about eight inches, so that they form parallelograms when removed from the bed. These are then placed in heated rooms, and being still further dried, are fit for the market.

POTASH, NITRATE OF, KO.NO.3. Syn. Nitre, Saltpetre, Prisomatie nitre. (Nitrate de potasse, Fr.; Salpetersaures Kalii, Germ.) For the mode of purification, see Gunpowder. This well known and useful salt is found native in various parts of the world, more especially in tropical climates. The formation of nitre in the earth appears to be much facilitated by warmth.

Preparation. 1. By lixiviation of earth impregnated with the salt. The earth is heated with water in tanks or tubs with false bottoms, and after sufficient digestion the solution is run off and evaporated to crystallization. The nitre procured by the first operation is exceedingly impure, and contains large quantities of chloride of potassium, and some sulphate of potash. By repeated crystallizations the salt may be obtained pure. If the crude product of the lixiviation contains, as is often the case, the nitrates of lime or magnesia, they may be got rid of by the addition of carbonate of potash; the earths are precipitated as carbonates, and may be filtered off, while an equivalent quantity of nitrate of potash is formed and remains in solution, thus:—

\[ \text{Ca(NO}_3\text{)}_2 + \text{K}_2\text{CO}_3 \rightarrow \text{CaCO}_3 + 2\text{KNO}_3. \]

2. The second mode of preparing nitre which we shall consider, is from nitrate of soda and chloride of potassium. On dissolving equivalent quantities of these two salts in water, and salting down, double decomposition takes place. The chloride of sodium may be removed from the hot concentrated fluid by means of shovels, while the nitrate of potash, being much more soluble in hot than in cold water, remains in solution, but crystallizes out on cooling. The decomposition takes place in accordance with the annexed equation:—

\[ \text{NaNO}_3 + \text{KCl} \rightarrow \text{NaCl} + \text{KNO}_3. \]

The above reaction is one of great interest and importance, inasmuch as it enables us to convert Peruvian or cubic nitre, as nitrate of soda is sometimes called, into the much more valuable salt, nitrate of potash. During the last war with Russia it was found that large quantities of chloride of potassium were exported, and found their way into that country. For some time no notice was taken, because the salt appeared too harmless to be a cause of war. Eventually it was found that it was entirely used in Russia for the purpose of affording nitrate of potash, by the process described. It need scarcely be said that the gunpowder made through the medium of our own chloride of potassium, was employed against our troops in the Crimea.

Nitre may also be prepared by neutralizing nitric acid by means of carbonate of potash, or the caustic alkali. The process is evidently too expensive to be employed, except for the purpose of experimental illustration, or under other special circumstances.

The formation of nitre in the earth of hot climates is probably in most cases due to the decomposition of nitrogenized organic matters. The subject of nitrification is one upon which some controversy has taken place. It is supposed by some chemists that the chief source of nitre is the ammonia produced during the decay of nitrogenous matters. The presence of bases appears to have a remarkable tendency to increase the production of the acid. It has been asserted that the ammonia which is produced suffers partial oxidation,
POTASH, NITRATE OF.

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the acid formed uniting with undecomposed ammonia to form the nitrate of that alkali. On the other hand, it has been argued that the ammonia does not suffer oxidation, but that the nitrogen produced during the decay of organic matter combines, at the instant of its liberation with oxygen, to form nitric acid, which unites with the bases present. Nitrate of ammonia, no matter how formed, suffers double decomposition in presence of the carbonates of the alkaline earths, the result being the production of the nitrates of lime and magnesia. It is owing to the presence of the two latter salts in the crude liquor obtained by lixiviating nitrified earth, that the addition of carbonate of potash is so important, and causes so great an increase in the produce of nitre. It has been insisted by some observers that the presence of nitrogenous organic matters is not essential to the production of nitre. In support of this it has been shown that large quantities of nitrates are often found where little or no organic matters are present. This has been explained by assuming that porous bodies have the power of absorbing water, oxygen, and nitrogen, and producing nitric acid from them. But it is evident that other forces exist capable of inducing the oxidation of atmospheric nitrogen. It has been experimentally demonstrated that nitric acid is produced during the discharge of atmospheric electricity. It is also probable that ozone plays an important part in the phenomena of nitrification. Perhaps the most of the chemists who have investigated the subject, have been too anxious to assign the formation of nitre to one particular cause, whereas the phenomena which have been noticed by different observers are in favor of the idea that several agencies are at work during the production of nitrates in the earth and in artificial nitre beds.

During the time that France was fighting single-handed against the rest of Europe, great difficulty was found in obtaining sufficient nitre for the production of the vast amount of gunpowder necessary to enable her artillery to be effectively supplied with ammunition. This led the French chemists to establish artificial nitre beds in various parts of the country. The success of the process may be judged of from the fact that they yielded 2,000 tons annually.

Chemical and physical properties.—Nitre crystallizes in colorless six-sided prisms. The crystals are anhydrous; large specimens, when broken, however, generally show the presence of a little moisture mechanically adhering to the interstices. If wanted in fine powder, it must therefore be first coarsely bruised, and then dried, after which it may be finely pulverized and sifted, without that tendency to adhere into lumps which would otherwise be observed.

By the careful application of heat, nitrate of potash may be melted without undergoing any decomposition or loss of weight. But if the heat be raised to redness it begins to decompose, the degree to which the change takes place depending on the amount of heat and the time of exposure. By carefully heating for some time, a large quantity of nitric of potash is formed, oxygen gas being evolved. If the heat be raised, or the exposure to a high temperature be continued, a large quantity of nitrogen accompanies the oxygen, and the nitre becomes more and more changed, until finally, a mixture of potash with peroxide of potassium is attained. If copper filings, clippings, or shreds be mixed with the nitre, the decomposition proceeds much more readily; and Wohler has proposed to prepare pure potash by this means. At high temperatures nitre is a potent agent of oxidation, so much, that the diamond itself is attacked and converted into carbonic acid, which unites with the potash. It was in this manner that Smithson Tennant first showed the diamond to consist of pure carbon. His mode of operating was to fuse the nitre with fragments of diamond in a tube of gold. Crystalized borax, which is said to equal if not exceed the diamond in hardness, is not attacked by fused nitre. A very striking experiment for the lecture table consists in pouring charcoal in powder into melted nitre retained at a red heat over a lamp. A violent deflagration takes place, and a considerable quantity of carbonate of potash is formed. The presence of the latter substance may be shown as soon as the capsule has become cold, by adding an acid to its contents, when a strong effervescence will take place. The oxidizing power of nitre is made use of in the arts in order to obtain bichromate of potash from chrome iron ore.

Nitrate of potash is sometimes used as a source of nitric acid, but nitrate of soda is in every way more economical. This will be evident when it is considered that it takes 101 parts of nitrate of potash to yield one equivalent of dry nitric acid (54 parts), whereas 85 parts of nitrate of soda yield the same amount of acid. Moreover, if nitrate of potash be used, it is essential to employ two equivalents of sulphuric acid to decompose one equivalent of the salt, for if only one were used, the residue of sulphate of potash being hard, and not very readily removable by water, considerable chances would be incurred of injuring the still; it is usual, therefore, to so adjust the proportions that the readily soluble bisulphate should be the residue. If, on the other hand, nitrate of soda be employed, the residue in the still being sulphate of soda, no difficulty is found in its removal.

This method of avoiding the presence of manganese. It often happens where the quantity of manganese is exceedingly small, as in rose quartz, that the green
POTASH, NITRATE OF.

coloration with soda or platinum foil cannot be obtained; if, however, a little nitre be added, and the testing be repeated, the reaction generally appears without any trouble.

Nitre of potash is greatly employed in the preparation of pyrotechnic mixtures. It ought always to be well dried and reduced to fine powder before being used.

Solubility of nitre in water at various temperatures.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Solubility (g/100g water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>4000</td>
</tr>
<tr>
<td>22</td>
<td>3450</td>
</tr>
<tr>
<td>26</td>
<td>2920</td>
</tr>
<tr>
<td>30</td>
<td>2500</td>
</tr>
</tbody>
</table>

From the above table it is evident that the solubility of nitre in water increases very rapidly with the temperature. Nitre is not unfrequently employed by the chemist for determining the percentage of sulphur in coals. For this purpose the coal, reduced to fine powder, is mixed with nitre and carbonate of soda, and projected by small portions into a silver crucible, maintained at a red heat. A platinum crucible must not be employed, as it is attacked by nitre in a state of fusion. The sulphur in the coal is converted, by the oxidizing agency of the nitre, into sulphuric acid; the latter can then be converted into sulphate of baryta, and the percentage of sulphur ascertained from its weight.

Estimation of the value of nitre.—A great number of processes have been devised for the determination of the percentage of pure nitre of potash in samples of the crude salt. All these processes are more or less incorrect, and a really accurate mode of determining the value of nitre has long been felt as a want by chemists. This want has only quite recently been supplied by Messrs. Abel and Bloxam of the Woolwich Arsenal, who have devoted much labor and skill to the subject, the importance of which, in connection with the art of war, can scarcely be over-estimated. Before detailing the new and successful process of the latter chemists, we will take a brief glance at the other methods commonly used for the purpose. The French process depends upon the principle that a solution, when saturated with one salt, is still capable of dissolving a considerable quantity of saline matter differing in its nature from the first. If, therefore, a saturated solution of nitre be poured upon pure nitre, no more is dissolved if the temperature remains the same as it was when the original solution was prepared. But if, on the other hand, the saturated solution of nitre be digested with an impure sample containing the chlorides of sodium, potassium, &c., the latter salt will be dissolved, and the pure nitre remaining can, after proper draining, &c., be dried and weighed. The loss of weight obviously represents the impurities removed. This process is subject to so many sources of error that the practical details need not be entered into.

Another mode of valuing nitre consists in fusing the salt, and, after cooling, breaking the cake; the fineness or coarseness and general characters of the fracture are the means whereby the greater or less value of the salt are ascertained. This process, which is known as the Swedish or Swartz's method, is far too dependent on the individual experience and dexterity of the operator to be of any value in the hands of the chemist whose attention is now directed to the valuation of saltpetre. Moreover, although those who are in the habit of using it possess some confidence in its correctness, it is quite evident that it is impossible for such an operation to yield results of analytical accuracy.

The Austrian method has also been used by some, but it is quite inadmissible as a general working process. It consists in ascertaining the temperature at which the solution crystallizes. Gossart's method consists in determining the value of the nitre by measuring its power of oxidation. The latter is accomplished by finding the quantity of protoxide of iron which it can convert into peroxide. If to an acid solution of protosulphate of iron nitric acid or a nitrate be added, the proto is converted into a persalt at the expense of a portion of the oxygen of the nitric acid, thus:

\[2 (FeO,SO_4) + NO_2 + SO_3 = FeO_3 + 2SO_2 + NO_4.\]

Theoretically this process is unexceptionable, but in practice it is liable to great errors.

M. Pelouze endeavored to improve the above process by using such an excess of the protosalt of iron that the nitre added should be able to convert only a portion of it into a persalt. The remaining protoxide was then converted into persalt by means of a solution of permanganate of potash of known strength. The data so obtained enabled the value of the nitre to be estimated. But even this process is liable to variations.

The next process which we shall notice is that which the chemists alluded to have finally settled upon as yielding the best results. It is that of M. Gay-Lussac. It depends on the fact that if nitrate of potash be heated with charcoal, or, in fact, any carbonaceous matters in excess, the nitrate is converted into carbonate of potash, the amount of which may be accurately estimated by means of a standard solution of sulphuric acid. The chlorides which may be present are unacted upon by the charcoal, and do not, therefore, influence
the result; but if sulphates be present they are reduced by the carbon to sulphides, which, in consequence of being decomposed by the sulphuric acid, may cause serious errors. Fortunately the amount of sulphuric acid present in nitre is seldom sufficient to cause any great error. Any nitrate of soda present would come out in the final result as nitrate of potash, and thus become another source of error; in practice this is seldom likely to occur.

The original process consists in weighing out 20 grammes (208-69 grains) of crude saltpetre, and mixing it with 5 grammes (27-17 grains) of charcoal, and 80 grammes (1384-7 grains) of chloride of sodium. The mixture is thrown little by little into a red-hot crucible, and, when the decomposition is over, allowed to cool. The residual mass is dissolved in water, filtered, and water passed through the filter until it amounts to 200 cubic centimetres, (12-2 cubic inches.) The amount of alkali is then ascertained with a burette and standard sulphuric acid. (See Alkaliometer.) Messrs. Abel and Blomax have minutely and laboriously studied this operation, and detected its sources of difficulty and error. Their researches have led them to employ the following modification.

Twenty grains of the sample are to be well mixed in a platinum crucible with 50 grains of finely-powdered resin, and 80 grains of pure dry common salt. The heat of a wire gauze flame is then applied, until no more vapor is given off. The crucible is then allowed to cool down a little, and 25 grains of chlorate of potash are added. A gentle heat is then applied until most of the chlorate is decomposed; the heat is then raised to bright redness for two or three minutes. The mass should be fluid, and free from floating charcoal. The mass, when cool, is removed to a funnel, and the crucible, &c., washed with boiling water. The mass is then dissolved in hot water, and the entire solution, colored by litmus, is neutralized with the standard acid. In the annexed table 20 grains of pure nitre were taken for each experiment:

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Nitre found</th>
<th>Nitre per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20:00</td>
<td>100:00</td>
</tr>
<tr>
<td>2</td>
<td>20:00</td>
<td>100:00</td>
</tr>
<tr>
<td>3</td>
<td>19:97</td>
<td>99:85</td>
</tr>
<tr>
<td>4</td>
<td>19:97</td>
<td>99:85</td>
</tr>
<tr>
<td>5</td>
<td>20:08</td>
<td>100:40</td>
</tr>
<tr>
<td>6</td>
<td>20:08</td>
<td>100:40</td>
</tr>
<tr>
<td>7</td>
<td>20:08</td>
<td>100:40</td>
</tr>
</tbody>
</table>

The authors, not yet satisfied, made 33 more experiments by this method. The mean result with pure nitre was 99-7 per cent.
The mean of 23 of the above experiments was 98-7 per cent.
The mean of the remainder was 100-7 per cent.

Subsequent experiments showed that greater accuracy might be obtained by substituting for the resin, pure ignited finely divided graphite, prepared by Professor Brodie's patented process. To perform this process 20 grains of the nitre are to be mixed with 5 grains of ignited graphite and 80 grains of salt. The general process is conducted in the manner described in the operation with resin. The results are very exact, and apparently quite sufficient for all practical purposes.—G. G. W.

POTASH, NITRITE OF, KO,NO2. When ordinary saltpetre, or nitrate of potash, is heated with sulphuric acid, in the cold, no special reaction becomes evident, as far as any evolution of gas is concerned; but if, previous to the addition of the acid, the nitre be strongly fused, it will be found, as soon as the admixture takes place, that red fumes are evolved. This arises from the fact that nitrate of potash, when subjected to strong ignition, is decomposed with evolution of oxygen, the nitrate becoming gradually converted into the nitrite of potash, thus:

\[ \text{KO,NO}_2 = \text{KO,NO}_2^+ + 20. \]

This reaction acquires great interest from the circumstance, that to its correct explanation was owing the commencement of the fame of the illustrious Swedish chemist Scheele. A pharmacist, at Upsula, having heated some saltpetre to redness in a crucible, happened, when it became cold, to pour vinegar over it, when, to his surprise, red fumes were evolved. Gahn was applied to for an explanation; but, unable to comprehend the matter, he applied to Bergmann; but even he was as much in the dark as Gahn. The explanation which these eminent chemists were unable to give, was supplied by the pharmacist's apprentice, the young Scheele. Bergmann, when informed by Gahn of Scheele's explanation, felt a strong desire to make his acquaintance, and ultimately they were introduced to each other.

Nitre of potash has acquired some importance of late years, owing to the valuable properties, as a decomposing agent, which have been found by chemists to reside in nitrous acid.

Preparation.—Nitrate of potash is to be fused at a red heat for a considerable time. When cold, the contents of the crucible are to be dissolved out with boiling water, and the nitrate of potash remaining is to be removed as far as possible by crystallization. The nitrite of potash may be obtained from the mother liquor by evaporation and subsequent
crystallization. It is a neutral salt, which deliquesces on exposure to the air. If a piece of strongly-fused nitre be put, when cold, into a solution of sulphate of copper, a very beautiful apple-green color is produced, of a tint which is seldom observed except in solutions containing the nitrate of that metal.—C. G. W.

PRINTING BLOCKS—ELECTRO. While this book has been passing through the press, Mr. H. G. Collins has taken out two patents, which are likely to prove of essential service to the publishing world. By the one he is enabled to take on vulcanized caoutchouc, prepared with an equally elastic surface, an impression in transfer from any steel or copper plate, wood block, stereotype, Lithographic stone, or, in fact, from an original drawing, if done in transfer ink on transfer paper, and increase or reduce the same to any required size. This is effected by applying the India-rubber in one case, after it has received the impression; and in the other, before the impression is made. In the first instance the impression is enlarged as the elastic material expands, in the other it is reduced by allowing the already expanded India-rubber to contract in its frame; then laying the expanded or contracted copy down upon stone, and treating it after the usual manner of lithography. This presents a vast field for adapting the plates of any work of acknowledged merit which may have cost some hundreds or thousands of pounds, and years to produce, to the wants of the public in these days of cheap and well-illustrated literature, by bringing out the same works in a reduced size, which, but for this plan, no publisher would think of attempting. Many plates, also, such as portraits, public buildings, or landscapes, may be enlarged and issued separately. This last application is particularly suitable for maps, as any one, from the size of a school atlas, may be taken and made to serve for the whole map, without the cost of engraving the same. The rapidity with which this alteration of size can be accomplished is not among the least of its recommendations; for an engraving that would take several months in the ordinary mode may be completed in from two to three days.

This patent offers the same facilities to a vast number of the manufacturers of the country, such as the lace trade, cotton printers, damask and m OHten houses, potteries, paper-hangings; in fact, to all and every one who employ art or design in their calling. It will be well to observe that the size cannot only be enlarged or diminished, as the case may be, but the pattern can be altered in form; thus a circular design can be made into an oval, if required. Mr. Collins, by his second patent, is enabled, after these impressions are once upon the stone, to make them into electro blocks, thus reducing also the cost of printing engraved plates, which is effected in the following manner:—The impression being placed on the lithographic stone or the zinc plate—either one or the other can be employed—acid is applied to abrade to a certain extent the stone or metal over the unprotected portions; when this is sufficiently deep a mould is taken in wax, the surface of which being prepared is subjected to the electrotype process, and thus a copper block is obtained.

Mr. C. has also a provisional specification for a third patent, by which he can by the assistance of photography, produce blocks for surface printing (without the aid of the engraver) in the course of a few hours. The whole of these patents are being brought into practical operation by the "Electro Printing-block Company."

PRINTING MACHINE. An American machine, the invention of R. Hoe and Company, of New York, has within the last two years (1860) been introduced to this country. Machines of this description have been made for The Times, and other newspaper offices, by Mr. Whitworth of Manchester. The following is Mr. Hoe's description of this machine.

A horizontal cylinder of about 43 feet in diameter is mounted on a shaft, with appropriate bearings; about one-fourth of the circumference of this cylinder constitutes the bed of the press, which is adapted to receive the form of types—the remainder is used as a cylindrical distributing table. The diameter of the cylinder is less than that of the form of types, in order that the distributing portion of it may pass the impression cylinders without touching. The ink is contained in a fountain placed beneath the large cylinder, from which it is taken by a duster roller, and transferred by a vibrating distributing roller to the cylindrical distributing table; the fountain roller receives a slow and continuous rotary motion, to carry up the ink from the fountain.

The large cylinder being put in motion, the form of types thereon is, in succession, carried to corresponding horizontal impression cylinders, arranged at proper distances around it, which give the impression of eight sheets, introducing one at each impression cylinder. For each impression cylinder there are two inked rollers, which vibrate on the distributing surface while taking a supply of ink, and at the proper time pass over the form, when they again fall to the distributing surface. Each page is locked up upon a detached segment of the large cylinder, called by the compositor a "turtle," and this constitutes the bed and chase. The column rules run parallel with the shafts of the cylinder, so as to bind the types near the top. These wedge-shaped column rules are held down to the bed or "turtle" by tongues, projecting at intervals along their length, and sliding in related grooves cut crosswise in the face of the bed; the space in the grooves between the column rules being filled with sliding blocks of metal, accurately fitted, the outer surface level with
the surface of the bed, the ends next the column rules being cut away underneath to receive a projection on the sides of the tongues and screws at the end and side of each page to lock them together, the types are as secure on this cylinder as they can be on the old flat-bed.

In the Times office there are two of these machines, one of them being a ten-cylinder machine, which is regularly employed to print 16,000 sheets an hour, and it appears capable of printing 18,000. It is only by means of these two American machines, and two of Applegath's, all working on the different sides of the paper, that the enormous supply required every morning can be produced.

The first successful application of steam, as a motive power, to printing presses with a platen and vertical pressure, was made in the office where this book is being printed. Convinced of the superiority of the impression made by flat as compared with that of cylindrical pressure, Mr. Andrew Spottiswoode, assisted by his chief engineer, Mr. Brown, succeeded, after many experiments, in perfecting a machine which combines the excellence of the hand press with more than four times its speed, and a uniformity in color which can never be attained by inking by hand. The main point of the invention is the endless screw or drum which takes the carriage and type under the platen, and after the impression is taken returns it to its original position.

PRINTING AND NUMBERING CARDS. It will be remembered in the early days of railway travelling, the ticket system then in vogue at the various stations was a positive nuisance; as every ticket before it was delivered to a passenger had to be stamped, and torn out of a book—thus causing the loss of considerable time to travellers when many passengers were congregated. The first to remedy this was Mr. Edmondson, who constructed an ingenious apparatus for printing the tickets with consecutive numbers, and also dating the same. This gave great facilities for checking the amounts of the station clerks; but owing to the imperfect manner of inking, consequent on the construction of the apparatus, the friction to which the tickets were exposed, before they were delivered up, in a great manner obliterated the printing, and occasionally rendered them quite illegible. By Messrs. Church and Goddard's machine for printing, numbering, cutting, counting and packing railway tickets, this difficulty is removed, and great speed is attained in manufacturing tickets, as the several operations are simultaneously performed. Pasteboard cut into strips by means of rollers is fed into the machine, by being laid in a trough, and brought under the prongs of a fork, (working with an intermitting movement,) which pushes the strips successively forward between the first pair of a series of guide or carrying rollers. There are four pairs of rollers, placed so as to conduct the strip through the machine in a horizontal line; and an intermittent movement is given them for the purpose of carrying the strips forward a short distance at intervals. The standards of the machine carry, at the top, a block termed the "pattern," as it acts the part of the press-head in the common printing machine—portions of it projecting downwards between the upper rollers of the first and second, and second and third pairs of carrying rollers, to the horizontal plane, in which the pasteboard lies, so as to sustain it at those points while it receives the pressure of the printing types and numbering disk, to which it is referred to. The types to designate the nature of the ticket, as "Birmingham, First Class," are secured in a "chase," upon a metal plate or table, which also carries the numbering disk for imprinting the figures upon the cards; and the table by a can action is alternately raised, to bring the types and numbering disk in contact with the pasteboard, and then lowered into a suitable position, to admit of an inking roller moving over the types and numbering disk, and applying ink thereto. The table likewise carries at one end a knife, which acts in conjunction with a knife-edge, projecting downwards from the fixed head of the machine, and thereby gives the cross-cut to the strips between the third and fourth pair of carrying rollers,—thus severing each into a given number of tickets. The strip of pasteboard which is fed into the machine stops on arriving at the second pair of carrying rollers; and, on the ascent of the printing table, the types print on that portion which is between the first and second pairs of rollers. The strip then passes on to the third pair of rollers, where it stops; and, on the table again ascending, the numbering disk imprints the proper number upon the pasteboard between the second and third pairs; the type, in the meanwhile, printing what is to be the next following ticket. On the next ascent of the table, the strip has advanced to the fourth pair of rollers; and the knives being now brought into contact, the printed and numbered portion of the strip is severed. The now completed ticket is lastly delivered by the fourth pair of rollers into a hollow guide piece, and conducted to a box below, provided with a piston, which, to facilitate the packing of the tickets in the box, can be adjusted to any height to receive the tickets as they fall. To avoid the necessity of having to count the tickets after they are taken from the receiving box, a counting apparatus, connected with the working parts of the machine, is made to strike a bell on the completion of every hundred or more tickets, so as to warn the attendants to remove them from the box. The inking apparatus is assimilated in character to self-inking inkers in ordinary printing presses; and the numbering discs are worked in a manner very similar to those for paging books.
A simple arrangement of apparatus for printing and numbering cards has been introduced by Messrs. Harrild and Sons. The types are fixed in a metal frame, which also carries the numbering discs. This frame is mounted on a rocking shaft, and is furnished with a handle, whereby it is rocked to bring down the types and discs upon the card, to produce the impression. When the frame is raised again, the units disc is moved forward one figure, and the types are inked by a small roller, which takes its supply of ink from an inking table, that forms the top of the frame.

M. Baranowski, of Paris, invented a machine for printing and numbering tickets, and also indicating the number printed. The types and numbering discs are carried by a horizontal rotating shaft, upon which, near each end thereof, is a metal disc; and upon the periphery of these discs a metal frame is affixed, which carries the types and numbering discs, and corresponds in curvature with the edge of the discs. The types for printing the inscription upon the ticket are arranged at right angles to the length of the shaft, which position admits of some lines of the inscription being printed in one color, and the remainder in another color. In the type frame a slot or opening is formed lengthwise of the shaft; and behind this opening are three numbering discs, and three discs for indicating the quantity of tickets numbered—all standing in the same row. The numbering discs are made with raised figures, which project through the slot, in order to print the number upon the ticket; and on the peripheries of the registering discs (which move simultaneously with their corresponding numbering discs) the figures are engraved. The tickets to be printed and numbered are placed in a rectangular box or receiver, having at the bottom a flat sliding piece, which has a reciprocating motion for the purpose of pushing the lowest ticket out of the box, through an opening in the front side thereof, beneath an elastic pressing-roller of India-rubber; the type-frame (with the types and figures properly inked) is at the same time brought, by the rotation of its shaft, into contact with the ticket beneath the pressing roller, and as it continues its motion, it causes the ticket to move forward beneath the pressing roller, and to be properly printed and numbered. The ticket then falls from the machine; and the type-frame, carried on by the revolution of the shaft, brings that number on the registering discs which corresponds with the number printed on the ticket, under a small opening in the case, covered with glass; whereby the number of tickets printed will be indicated.

PRINTING ROLLERS. Elastic inking rollers were introduced by Messrs. Donkin and Bacon. They are made of a mixture of glue and treacle, or of glue and honey; the American honey, it is said, being preferred. 1 pound of good glue is softened by soaking in cold water for twelve hours, and then it is united, by means of heat, with about 2 pounds of ordinary treacle.

Messrs. Hoe and Co. give the following directions for making and preserving composition rollers:—For cylinder-press rollers, Cooper's No. 1. x glue is sufficient for ordinary purposes, and will be found to make as durable rollers as higher priced glues. Place the glue in a bucket or pan, and cover it with water; let it stand half an hour, or until about half penetrated with water, (care should be used not to let it soak too long,) then pour it off, and let it remain until it is thoroughly melted. If too thick, add a little water until it becomes of proper consistency. The molasses may then be added, and well mixed with the glue by frequent stirring. When properly prepared, the composition does not require boiling more than an hour. Too much boiling cinders the molasses, and the roller consequently will be found to lose its suction much sooner. In proportioning the material, much depends upon the weather and temperature of the place in which the rollers are to be used. 8 pounds of glue to 1 gallon of sugar-house molasses, or syrup, is a very good proportion for summer, and 4 pounds of glue to 1 gallon of molasses for winter use. Hand-press rollers may be made of Cooper's No. 14 (one and a quarter) glue, using more molasses, as they are not subject to so much hard usage as cylinder-press rollers, and do not require to be as strong; for the more molasses that can be used the better is the roller. Before pouring a roller, the mould should be perfectly clean, and well oiled with a swab, but not to excess. Rollers should not be washed immediately after use, but should be put away with the ink on them, as it protects the surface from the action of the air. When washed and exposed to the atmosphere for any length of time, they become dry and skinny. They should be washed about half an hour before using them. In cleaning a new roller, a little oil rubbed over it will loosen the ink, and it should be scraped clean with the back of a case knife. It should be cleaned in this way for about one week, when it may be used. New rollers are often spoiled by washing them too soon with lye. Camphene may be substituted for oil; but owing to its combustible nature it is objectionable, as accidents may arise from its use.

PROVING MACHINE. The drawing shows a useful machine for testing the quality and power of India-rubber springs, designed by Mr. George Spencer, of the firm of Geo. Spencer and Co., and used by them for that purpose. Fig. 920 shows an elevation, partly
in section, of the machine; fig. 576 a plan of the same. \( A \) is a strong cast-iron frame, supported by two cast-iron standards; \( B \) is a sliding piston, working in a hole cast in the end of frame \( A \), one end of which impulses against the short arm of a strong cast-iron lever, \( D \), forming one of a system of compound levers as shown, having fulcrums at \( F \) and \( J \), and provided with a Salter's balance, \( G \), to register the power exerted by the spring. At the other end of frame \( A \), a brass nut, \( H \), is placed in a hole in the frame, through which a square-threaded screw, \( S \), works by means of the handle, \( M \), or by a long lever of wrought iron, according to the power of spring to be tested. The spring to be tested is placed between the two sliding guide plates, \( x \), \( x' \), and a wrought-iron bolt passed through the plates, \( x \), \( x' \), and spring, \( z \), and passing into the hollow piston, \( C \), for the purpose of keeping the spring in correct position, and receiving in its hollow head, \( m \), the end of the screw, \( s \). The action may be thus described:—The handle, \( M \), being turned, the screw, \( S \), advances and pushes on the plate, \( x' \), by means of the bolt- head, \( z \). The other plate, \( n \), rests against the piston, \( C \), and is pressed against it by the intervening spring, \( z \). The leverage, \( N \), is so arranged that 1 lb. on the dial is equal to 2 cwt. on the spring, or, in other words, is 1 in 224. Springs of a force of 20 tons can be tested by this machine safely. See CAOUTCHOUC.

PRUSSIAN BROWN. A fine deep brown color obtained by adding the yellow prussiate of potash (ferroprussiate) to a solution of sulphonate of copper.

PURPLE DYES. The purple dyes now obtained by more or less complex processes from coal tar are so incomparably superior to any others, both in brilliancy and permanence, that their production has opened up a new era in dyeing and calico-printing. The process of Mr. Perkin, the discoverer of aniline purple, is simple in principle, but the operations, from the production of the coal tar to the formation of the pure purple, are so numerous, and require to be conducted on such a large scale, that the successful manufacture involves the necessity for large capital and considerable chemical skill. Mr. Perkin's process involves the following operations:

1. Production of benzole from coal tar by fractional distillation.
2. Conversion of benzole into nitro-benzole by the action of nitric acid.
3. Conversion of nitro-benzole into aniline.
4. Production of neutral sulphate of aniline.
5. Decomposition of sulphonate of aniline by bichromate of potash.
6. Washing with water of the precipitate by bichromate of potash.
7. Drying of the washed precipitate.
8. Extraction of the brown impurity contained in the precipitate.
9. Extraction of the purple coloring matter.

An outline of the process contained in Mr. Perkin's specification will be found in the article ANILINE.

Numerous patents have been taken out for the production of colors more or less resembling Perkin's purple. J. T. Beale and J. N. Kirkham employ bleaching powder as the oxidizing medium. They take a saturated solution of aniline in water, and add to it acetic acid and bleaching powder until the desired tint is acquired. They then use the fluid so procured for dyeing. It is obvious that some process of concentration must be employed...
to enable so weak a fluid to be employed in calico-printing. Upon the latter point the patent process does not enter at sufficient length to enable us to judge of the practicability of producing colors of the great strength required for printing on with albumen. Messrs. Beale and Kirkham, by modifying the nature of the salt and the state of concentration of the fluids employed, obtain various shades of color from blue to lilac.

Mr. R. D. Kay, in his patent of the 7th May, 1859, treats acetate, sulphate, or hydrochlorate of albumine, with peroxide of manganese, peroxide of lead, or chloride of lime.

Mr. David S. Price, in his patent of the 23rd of May, 1859, claims the use of peroxide or sesquioxide of manganese, and also peroxide of lead, as his agent of oxidation. By varying the quantities of his ingredients he obtains three colors, viz, violet, purpureine, and roseine.

C. H. G. Williams patents the green manganate of potash as the oxidizing agent. By this means a part of the albumine is converted into a brilliant red dye of great beauty, and another part into an equally brilliant purple. The two colors are separated by taking advantage of the fact that the purple is precipitated by a solution of the reagent, whereas the red color remains in solution, and can be concentrated by evaporation.

In dyeing and printing with these colors it is necessary with vegetable fabrics to use mordants; but animal fabrics absorb the colors with great avidity without the use of any mordant.

For cottons, perehloride of tin, followed by sumach, or stannate of soda and sumach, are the best mordants. Mr. Perkin recommends tartaric acid to be added to the bath in dyeing; but in practice this recommendation is not generally followed.

For printing, the purple is mixed with albumen; and after printing with the mixture the color is fixed by steaming. Sometimes a mordant is printed on, and the pattern is obtained by passing the mordanted cloth through a bath of the color. The purple may be rendered of a bluer and very lovely tint by adding to the mixture of dye and albumen a little carmine of indigo; Prussian blue is also sometimes used for the same purpose. In selecting patterns to be printed in purple, it must not be forgotten that the beauty of the tint is greatly enhanced by the proximity of blacks properly arranged.

Very fine purples, but decidedly inferior to Mr. Perkin's color, are now prepared from linters; they are also tolerably permanent. They are, nevertheless, liable to the drawback of becoming red in contact with strong acids. Strange to say, however, the orchil purples when properly made resist very well the action of weak acids. The color-producing acids are obtained by treating the liechens with an alkaline base, which forms a soluble salt. The filtered liquid on treatment with an acid gives an abundant precipitate. It is this latter which, by proper treatment, yields the "French purple." The following is an outline of the process contained in a patent granted to William Spence, (being a French communication,) dated 1st May, 1858.

The precipitate obtained as above is moistened with sufficient ammonia to dissolve it. On boiling, the solution becomes orange yellow; it is then exposed to the air at ordinary temperatures, until it becomes red. The fluid is then heated in very shallow vessels to a temperature between 100° and 140° Fahr., until it becomes of a violet color, which is unalterable by weak acids, and which will dye permanent colors on silk or wool, without the aid of mordants.

This purple color can be thrown down from the liquid by saturation with an acid. The precipitate, after being filtered off and properly dried, is in a fit condition for dyeing or printing.

Like Perkin's purple, various shades may be obtained by using the orchil purple in combination with carmine of indigo for violets, and earthamus, or coelichium, for reds.—C. G. W.

PYROLIGNEOUS ACID. A new mode of distilling wood and producing this acid has been introduced by Mr. W. H. Bowers, of Manchester. In the rectangular retort which is used there are two revolving drums, one at each end. On these drums are endless chains; on these chains there is formed a flat surface by means of bars laid across. A hopper supplies this surface with the sawdust or other material to be heated. The surface is somewhat inclined. A very small engine is used to set the endless chain in motion. The sawdust is carried from the upper end of the retort to the lower, during which time it is exposed to heat and becomes distilled. At the lower end, as it is turning over the drums, it falls in a carbonized state into water. The vapors are carried away by pipes, as in the usual method, and the water joint at the lower part of the retort prevents any escape in that direction, whilst the thickness of the mass of sawdust passing into the retort readily prevents any from passing out there. It is said that one retort can do the work of five of those made on Halliday's plan with the screw. Two of them produce with slow motion 2,500 gallons of acid in six days. The motion may be increased at will, and heat regulated accordingly. There are scrapers to prevent charcoal clogging the bars forming the inclined plane, and the apparatus does not require to be stopped for any purpose of cleansing. It feeds and discharges continuously, from month to month.

Sawdust, wood turnings, small chips, spent dye wood, and tanners' bark, peat, and such
PYROXILIC SPIRIT.

like ligneous, and carbonaceous substances, are distilled, and the carbon discharged as shown.

It is believed also that the distillation is effected more rapidly, and the gases more directly removed by this method, than by any other.

Fig. 577 is a longitudinal section taken through the middle of the retort or rectangular vessel a, a, a; b, b are the revolving drums on which the endless chain e, e, e revolves; f, f are cross-bars or scrapers; g, g are tubes to convey the gases, one from the lower and one from the higher point of the moving plane; h is a hopper filled with sawdust and other material to be distilled; the supply is regulated by two small cog-wheels i, i; j, j, the fireplace; k, k, the flues; m is a cistern showing the level of the water and the carbon falling into it, the lower part of the retort dipping into it.

PYROXILIC SPIRIT. Syn. Pyroligneous spirit, Pyroligneous ether, Wood-spirit, Wood-naphtha, Methylic alcohol, Hydrate of methyle, Hydrated oxide of methyle. C\textsubscript{4}H\textsubscript{6}O\textsubscript{2} = C\textsubscript{3}H\textsubscript{4}O\textsubscript{2}H\textsubscript{2}O. Density of strongest wood-spirit at 52\textdegree, 0.8179. Density at 68\textdegree, 0.788. Density of vapor, 1.12 = 4 volumes. Boiling-point, 190\textdegree F.

Wood-spirit was first recognized as a distinct substance by Taylor, in 1812. Its true nature, however, was unknown until the appearance of the important research of MM. Dumas and Peligot, in 1835.

Pyroxylic spirit is obtained from the liquid products of the distillation of wood by taking advantage of its superior volatility. The crude wood-vinegar, if distilled per se, yields up to a certain point highly impure and weak spirit. It is, however, free from ammonia and alkaloids. If, on the other hand, the vinegar is first neutralized by lime or soda previous to the distillation of the spirit, it is rendered more free from acetate of methyle and some other impurities, but it then contains alkaloids and ammonia. At times the quantity of the latter substance present is so large that the spirit smokes strongly on the approach of a red dipped in hydrochloric or acetic acid. In order to apply this test it is obvious that the hydrochloric acid must be diluted until it does not flame by itself. By repeated rectifications over lime or chalk, rejecting the latter portions, the wood-spirit may be obtained colorless, and of a strength varying from 80 to 90 per cent. of pure spirit, the specific gravity being from 0.870 to 0.882.

Inasmuch as wood-spirit boils at a temperature far less than the point of effusion of the impurities ordinarily found in it, it may always be greatly improved in solvent power, appearance, and odor, by mere rectification on the water bath or in a rectifying still. But, nevertheless, a certain quantity of the more volatile impurities always accompany the methylic alcohol, being carried over with its vapor. Among the foreign bodies may be mentioned the hydrocarbons of the benzole series. These may be entirely removed by mixing the crude spirit with three or four times its volume of water; the hydrocarbons are thus rendered insoluble and rise to the surface of the fluid. By means of a separator the lower layer may be removed, and after two or three rectifications, at as low a temperature as possible, the spirit may be procured quite clean.

To obtain wood-spirit quite pure it is generally recommended to mix it with chloride of calcium, and again rectify on a steam or water bath. By operating in this manner, the methylic alcohol combines with the chloride of calcium, forming a compound not decomposable at the temperature of the water bath. The impurities present therefore distil away, leaving in the still a compound of pure methylic alcohol with chloride of calcium. But this latter compound possesses little stability, and may be decomposed by the mere addition
of water, which liberates the spirit. It is then to be distilled away from the salt, and after one or two rectifications over quicklime will be quite pure.

It is highly important that wood-spirit should be of considerable purity if required for the purpose of dissolving the gums. It is true, that as far as its use for dissolving shellac is concerned, there is no need for extreme purity, as shellac will dissolve in most specimens of wood-spirit. But it is not in this case the more solvent power that is required; for if a solution of shellac in impure wood-spirit is employed by hatters, the vapor evolved is so irritating to the eyes that the workmen are unable to proceed. If the spirit has the property of fusing on the approach of a rod dipped in acetic or hydrochloric acids, it may be taken for granted that it will be incapable of dissolving gum sandarach. This arises from the fact that such spirit has been distilled from an alkaline base, such as lime or soda, and contains alkaldoids, ammonia, and various other impurities which destroy its solvent power. The alkaline reaction may be destroyed and the spirit rendered fit for use by adding 2 or 3 per cent. of sulphuric acid and then distilling. The alkaldoids and many other impurities will then be retained, and the spirit may either be used at once or still further purified by dilution with water and subsequent rectification. It is possible to combine the two processes at one operation, by diluting the spirit with four times its bulk of water, and adding just enough oil of vitriol to the diluted liquid to give it a faint acid reaction to litmus paper. It is absolutely essential to the success of this process that the mixture of spirit water and acid be perfectly well mixed.

A wood-spirit which refuses to dissolve sandarach may often be rendered a good solvent by adding from 5 to 7 per cent. of acetone. See Acetone.

When wood-spirit is required in a state of extreme purity for the purpose of research, it may be obtained by distilling oxalate of methyl with water. Oxalate of methyl, or methyl oxalate ether may be obtained by distilling equal parts of sulphuric acid, oxalic acid, and wood-spirit. The distillate when evaporated very gently yields crystals of the compound in question. As it does not volatilize below 223° F., the rectort containing the materials for its preparation requires to be pretty strongly heated to bring the ether over. It may be purified by sublimation from oxide of lead.

Pure methyl alcohol is a colorless transparent liquid, neutral, very inflammable, burning with a blue flame like common alcohol. It has a very nauseous flavor, and is fiery in the mouth. It dissolves in any proportion in water, alcohol, or ether, and is a good solvent for fatty bodies and certain resins. It is miscible with essential oils.

Wood-spirit may be detected, according to Dr. Ure, even when greatly diluted with alcohol, by the brown color which it assumes in presence of solid caustic potash. Even when alcohol contains only 2 per cent. of wood-spirit, it acquires a yellow tint in 10 minutes on addition of powdered caustic potash. In half an hour the color becomes brown.

According to Mr. Maurice Scanlan, wood-spirit may be distinguished from acetone (with which it appears to have sometimes been confounded in medicine) by the action of a saturated solution of chloride of calcium, which readily mixes with the former, but separates immediately from the latter.

Wood-spirit is but seldom employed now in the arts, as it is generally cheaper and more convenient to use the mixture of 90 parts of spirit of wine with 10 parts of purified wood-spirit, which is now permitted by Government to be employed free of duty under the title of "methylated spirit."

The theoretical constitution of methyl alcohol is of course represented differently by various chemists. The radical theory regards it as the hydrated oxide of methyl. The formula being C\(\text{CH}_3\)O,\(\text{H}_2\). Another theory assumes it to be methyl ether, (the olefiant gas of the methyl series,) plus two equivalents of water: thus, C\(\text{H}_3\)\(\text{O}\). But the most convenient method of viewing it is, perhaps, by using the water type, and considering it as two equivalents of water in which one atom of hydrogen is replaced by methyl, thus:—

\[
\text{C}^\text{H}_3\text{O}^\text{H}\\\text{H}\\
\]

This method of regarding it has the advantage of enabling us to give a direct and simple definition of alcohols and ethers. Thus, an alcohol may in this manner be defined as two atoms of water in which one atom of hydrogen is replaced by an electro-positive radical, while an ether is to be looked upon as two atoms of water in which both atoms of hydrogen are replaced by the electro-positive radical.

Methyl alcohol, treated with solution of bleaching powder, yields chloroform, but the resulting product is not so fine as that prepared from the viuee alcohol. In fact, methyl alcohol is seldom or never found in commerce of such purity as to enable good chloroform to be prepared by the action of chloroide of lime. Moreover it should be mentioned that so acid and pungent are the products of the action of chlorine on the bodies accompanying crude wood-spirit, that great danger would be incurred in using a chloroform containing even minute traces of them. The following equation represents the action of the chlorines of the bleaching powder on wood-spirit:—
WOOD-SPIRIT.

Wood-spirit unites with chloride of calcium with such energy that the liquid enters into solution. The product of the union is sufficiently stable to endure a heat considerably above the boiling-point of water, without giving off the alcohol. Water, however, destroys the compound, and enables the spirit to be distilled away on the water bath.—C. G. W.

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QUININE.

This alkaloid is found, together with four other alkaloids, in the cinchona barks, of which there are numerous varieties, some containing principally quinidine, as the Calisaya or yellow bark, which is the most valuable of all the barks on that account; others containing principally quinidine and cinchonine, with but little quinine. Quinine is the principal of these alkaloids, and is now manufactured in a very large scale for medicinal purposes, it being a valuable tonic and febrifuge.

It was usually prepared from the C. calisaya, but, owing to the scarcity and high price of this bark, several of the inferior barks have been employed in its manufacture, and on that account the quinine which is usually employed contains some of the other alkaloids. The sulphate is the only salt of quinine which is manufactured for commercial purposes, and is generally known, though improperly, as "Disulphate of quinine."

The following is the process most generally followed in the manufacture of this salt:—The coarsely-powdered bark is digested with hot dilute sulphuric or hydrochloric acid for one or two hours; the liquor is strained off, and the bark treated with a fresh portion of still more dilute acid for the same time. This process may be repeated a third time, but the liquor then obtained, containing so little quinine, is used for a fresh portion of bark. The liquors from the first and second digestion are strained and mixed, and are then mixed with lime, magnesia, or carbonate of soda, until the liquid acquires a slight alkaline reaction, which may be known by its turning red litmus paper blue. Owing to the solubility of quinine, to a certain extent, in milk of lime and chloride of calcium, carbonate of soda is the best to be used for this purpose. A precipitate is formed, which is separated from the supernatant liquid by straining through a cloth. This dark-colored mass, which contains the alkaloids, coloring matter, some lime, and some sulphate of lime,—these latter, of course, only when both lime and sulphuric acid have been used in the process,—is treated with boiling ordinary alcohol, which dissolves the alkaloids and coloring matter. This solution is filtered, and the greater part of the alcohol removed by distillation, when a brown viscid mass remains; this is treated with dilute sulphuric acid, till the solution remains slightly acid; this solution is then digested with animal charcoal, filtered, evaporated, and allowed to cool, when the sulphate of quinine crystallizes out, together with some sulphate of quinidine or cinchonine, according to the barks which have been employed; but, owing to the greater solubility of these latter salts than the sulphate of quinine, they principally remain in the mother liquors. When more animal charcoal has not been used, the sulphate of quinine is likely to be contaminated with some sulphate of lime, formed by the action of the sulphuric acid on the lime in the animal charcoal; and in this process also some quinine is likely to be precipitated by the lime and lost in the animal charcoal.

In order to separate the sulphate of quinine thus obtained from the sulphates of quinidine and cinchonine, advantage is taken of the greater solubility of the two latter salts, as above mentioned, and by several crystallizations the sulphate of quinine may be obtained nearly free from these salts. The quantity of sulphate of quinine obtained from each pound of bark of course varies with the bark used. Some of the best calisaya bark will yield half an ounce of the sulphate from every pound of bark, while many other barks which are used in the manufacture of sulphate of quinine do not yield a quarter of an ounce.

A process has been patented by Mr. Edward Herring for the manufacture of sulphate of quinine without the use of alcohol, and it yields the article known as hospital sulphate of quinine at the first crystallization and without the use of animal charcoal. The following is the outline of the process:—The powdered bark is boiled in solution of caustic alkali, (soda preferred,) which removes the useless extractive gummy matters and coloring matter. After being well boiled, the bark is washed and pressed. This process of boiling with alkali, &c., may be repeated, if necessary, and the bark, after being well washed and pressed, having become decolorized, is boiled with dilute sulphuric acid, being kept constantly stirred whilst boiling. After the separation of the liquid, the bark is boiled with a second portion of dilute acid, and sometimes with a third; but the liquid from the last boiling is kept to be used for a fresh portion of bark. The first and second portions are mixed, strained, and precipitated with some salt which precipitates the alkaloids; the precipitate is washed and pressed, and then digested with dilute sulphuric acid, which dissolves the alkaloids; this solution is evaporated and allowed to cool, when the sulphate of quinine crystallizes out, accompanied with some sul-

\[
\text{C}_4\text{H}_6\text{O}_4 + 4\text{Cl} = \text{C}_4\text{H}_6\text{O}_4 + 2\text{H} + \text{HCl.} 
\]
Quinine.

Phases of quinidine and cinchonine, if the bark employed contained these latter alkaloids in any quantity. The sulphate of quinine thus obtained is dried, and forms the unbleached or hospital quinine. When the sulphate of quinine is required quite pure, this is treated with pure animal charcoal, and subjected to two or three further crystallizations.

It will be seen that the principal points in this process are the extraction of the coloring matter by the caustic alkali and the use of pure animal charcoal in producing the perfectly white sulphate, which prevents completely the admixture of sulphate of lime with sulphate of quinine.

This process yields from 80 to 90 per cent. of the quinine contained in the bark employed; and to obtain the remaining 10 or 20 per cent. the blood-red solutions formed by boiling the bark with the caustic alkali are treated with dilute hydrochloric acid in excess, which retains in solution any alkaloids that are present. This solution is strained and mixed with lime. The precipitate thus formed is collected, pressed, dried, and powdered.

It is then digested with benzol, or any solvent which is not a solvent of lime. These various duties or preparations are well agitated with dilute sulphuric acid, which extracts the quinine, &c.; when allowed to settle, the benzol, oil of turpentine, or lavand, whichever has been used, rises to the surface. The acid liquid is then siphoned off and evaporated, and the sulphate of quinine obtained from it is purified by two or three crystallizations, when it yields a salt equal to that obtained by the first process, viz. the unbleached or hospital sulphate of quinine.

The sulphate of quinine of commerce is the neutral sulphate, and has the following composition:

\[ \text{C}_6\text{H}_4\text{N}_2\text{O}_4 \cdot 2\text{H}_2\text{SO}_4 \cdot 14 \text{aq.} \]

When pure it occurs as white spangles, or slender needles, which are slightly flexible, and possess a pearly lustre and an intensely bitter taste. It effloresces in the air, and loses about 12 atoms of water. (Baup.) It requires for solution, 740 parts of cold water and 50 parts of boiling water, 90 parts of alcohol at ordinary temperatures, and much less of boiling alcohol.

Its solution in acidulated water turns the plane of polarization strongly to the left, and presents a blue tint, which is due to a peculiar refraction of the rays of light on the first surface of the solution, and is termed fluorescence by Professor Stokes, who, as well as Sir John Herschel, has examined the cause of it, the latter referring it to cytophic dispersion. Heated to 212° F., sulphate of quinine becomes luminous, which is augmented by friction, and the rubbed body is found to be charged with vitreous electricity, sensible to the electroscope. It fuses easily, and in that state resembles fused wax; at a higher temperature it assumes a red color, and at length becomes charred. When a solution of quinine is treated with chlorine and ammonia, it yields a bright green solution, very characteristic of quinine.

Besides the neutral sulphate, there exists an acid sulphate, or bisulphate, of the following composition:

\[ \text{C}_6\text{H}_4\text{N}_2\text{O}_4 \cdot 2\text{H}_2\text{SO}_4 \cdot 16\text{H}_2\text{O} \]

It is formed by dissolving the neutral sulphate in dilute sulphuric acid, evaporating and crystallizing. It crystallizes in rectangular prisms, or silky needles. It is much more soluble in water than the neutral sulphate, requiring only 11 parts of water at ordinary temperatures to dissolve it. The solution reddens blue litmus paper.

It fuses in its water of crystallization, and at 212° C. loses 24.6 per cent. of water. (Liebig and Baup.) With sulphate of sesquioxide of iron, it forms a double salt, which crystallizes in octahedra resembling those of alum.

An interesting compound of iodine and bisulphate of quinine has been discovered by Dr. Henrath, which crystallizes in large plates, and by reflected light presents an emerald green color and a metallic lustre, but by transmitted light appears almost colorless. The point of interest in this compound is, that its crystals have the same effect upon a ray of light as plates of tournament, and have even been used instead of this latter substance.

Its composition is: \[ \text{C}_6\text{H}_4\text{N}_2\text{O}_4 \cdot \text{H}_2\text{SO}_4 \cdot 4\text{H}_2\text{O} \].

It may be obtained by dissolving the bisulphate of quinine in concentrated acetic acid, and adding to the heated liquid an alcoholic solution of iodine, drop by drop. After standing a few hours, the salt is deposited in large flat rectangular plates.

Adulteration of sulphate of quinine.—Owing to the high price of sulphate of quinine, it is often adulterated with various substances, as alkaline and earthy salts, boracic acid, sugar, starch, mannite margaric acid, salicine, sulphates of cinchonine and quinidine; the two latter substances will be found in most of the commercial sulphate of quinine, and are not looked upon as fraudulent mixtures when present only in small quantities, arising then from the imperfect purification of the sulphate of quinine. Sometimes, however, sulphate of cinchonine is present in large quantities, and this is effected by briskly stirring the solution from which the sulphate of quinine is crystallizing, when, although under other circumstances the sulphate of cinchonine would remain in solution, it will by this agitation be deposited in a pulverulent form, together with the sulphate of quinine. No doubt this fraud has been practised to a considerable extent.
The inorganic substances may be easily detected by indurating some of the suspected salt, when they will be left as ash. When some of the suspected sample is dissolved in dilute sulphuric acid, the muriatic acid would remain undissolved; if we then add to the solution a slight excess of baryta water, the sulphuric acid and quinine will be precipitated; the excess of baryta is precipitated by carbonic acid, the solution is then boiled and filtered, when the sugar, mannitate, and salicine remain in solution, and may be detected afterwards. The presence of salicine may be detected directly in sulphate of quinine by the addition of sulphuric acid, when it becomes red if salicine be present. Starch is detected by solution of iodine, with which it forms a deep blue compound. Boracic acid is dissolved by alcohol, and is recognized by the green tinge given to the flame of the ignited alcohol. For the discovery of cinchonine, several processes have been proposed. The one most generally adopted, and perhaps the best, is that known as Liebig's process, which depends on the difference of solubility, in ether, of quinine and cinchonine. It consists in putting into a test tube 10 grains of the sulphate of quinine with 120 grains of ether, then adding 10 or 20 drops of caustic ammonia; it is then briskly shaken. If the sulphate of quinine under examination contains no cinchonine, we obtain two layers of liquids, the one of water containing sulphate of ammonia, and the other ether holding the quinine in solution; if the salt contained cinchonine, this would remain suspended at the surface of the watery layer. The same process will detect quinidine also when present in quantities exceeding 10 per cent. of the sulphate of quinine; but the great distinction between quinidine and quinolinic is their deportment with oxalate of ammonia, this reagent causing, in a solution of sulphate of quinine, a precipitate of oxalate of quinine; whereas, the oxalate of quinidine being very soluble in water, no precipitate is formed by the addition of oxalate of ammonia to a solution of its salt.

**Determination of the quantity of quinine in samples of cinchona barks.**

In commerce the value of a cinchona bark depends on the quantity of crystallizable quinine which it will yield; it is therefore not sufficient to determine the amount of quinine which it contains, as the whole of this may not be convertible into crystallizable sulphates. In order to be accurate not less than a pound of bark should be used, and even then the result is often from 20th to 25th less than can be obtained on the large scale, where the loss in the process is much less in proportion. (Pereira).

Several processes have been employed for determining the quantities of alkaloids in cinchona barks.

Perhaps as good a process as any is, to exhaust a known quantity of bark by boiling with dilute acid; the solution is filtered, and the residue washed, the washings being added to the other liquid; it is then digested with pure animal charcoal, the solution again filtered, and the alkaloids precipitated by carbonate of soda; they are then collected, dried, and digested with ether to separate the quinine; after the evaporation of the ethereal solution, the quinine is dissolved in dilute sulphuric acid, the solution is evaporated, exactly neutralized by ammonia, and allowed to cool, when the sulphate of quinine crystallizes, which is collected, dried, and weighed; the quantity of the mother liquor being, of course, a cold saturated solution of sulphate of quinine, and knowing the solubility of sulphate of quinine in water, the quantity remaining in the solution may be determined and added to the former weight.—H. K. B.

**RAILS.**

The manufacture of iron rails has, with the extension of our railway system, increased in a remarkable manner. This is, however, rather a subject for a treatise on mechanical engineering, than for a Dictionary of Manufactures. A short notice only will therefore be given.

In 1829, Mr. Birkinshaw patented an improvement in the form of hammered iron rail. The malleable iron rails previously used were bars from two to three feet long, and one to two inches square; but either the narrowness of the surface produced such injury to the wheels, or by increasing the breadth their cost became so great, as to exceed that of cast iron, which consequently was preferred.

It was to remedy these defects in the malleable form, and at the same time to secure the same strength as the cast iron, that Mr. Birkinshaw made his rails in the form of prisms, or similar in shape to the cast-iron ones of the most approved character. Fig. 578 shows a side view of this kind of rail; fig. 579, a plan, and fig. 580, a section of the same rail cut through the middle.

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These rails are made by passing bars of iron, when red hot, through rollers with indentations or grooves in their peripheries, corresponding to the intended shape of the rails; the rails thus formed present the same surface to the bearing of the wheels, and their depths being regulated according to the distance from the point of bearing, they also present the strongest form of section with the least material. See ROLLING MILLS.

Malleable iron rails are now always employed. An objection has been urged against these rails on the ground that the weight on the wheels rolling on them expanded their upper surface, and caused it to separate in thin laminae. In many of our large stations rails may be frequently seen in this state; layer after layer breaking off, but this may be regarded rather as an example of defective manufacture than any thing else. It is true, Professor Tyndal has referred to those laminating rails, as examples in proof of his hypothesis, that lamination is always due to, and is always produced by, mechanical pressure upon a body which has freedom to move laterally. Careful examination, however, convinces the writer that whenever lamination of the rail becomes evident, it can be traced to the imperfect welding together of the bars of which the rail is formed.

The weight of railway bars varies according to section and length. There are some of 40 pounds per yard, and some of 80 pounds, almost every railway company employing bars of different weight. Besides flat rails, which are occasionally still used, we have bridge rails employed, which have the form of a reversed U. These have sometimes parallel sides, or, as in dovetail rails, the sides are contracted. The T-rails are more easily manufactured than the Λ-rails, the difficulty of filing the flanges not being so great as in the latter rail.

Fig. 581 represents the old rail, and fig. 582 Mr. W. H. Barlow's patent rail, which is made to form its own continuous bearing. In section this rail somewhat resembles an inverted V, with its ends considerably turned outwards. This portion forms the surface by which the rail bears upon the ballasting, the apex of the Λ being formed with flanges in the ordinary form of rails; and the rail, therefore, beds throughout on the ballast. It can be very easily packed up and adjusted when out of place, and all the fittings of sleepers, chairs, and keys, are done away with, nothing being required besides the rails themselves, except a cross or tie-rod at the joints, to hold them at the proper distance asunder, so as to keep the gauge of the line.

RASP, MECHANICAL. The name given by the French to an important machine much used for mashing beet-roots. See SUGAR.

RATTANS. The stems of the Calamus rotang, of C. rudentum, and various species of palms. They are used for making chairs, as a substitute for whalebone, for walking-sticks, and many other purposes. We imported in 1858, 18,625,368 rattan canes, valued at £58,960.

REFINING GOLD AND SILVER. Since the object of this book is to treat more especially of the application of scientific processes to commercial undertakings, it would be out of place to give a detailed account of the processes by which gold and silver are refined, or rendered free from other metals. In the laboratory, where chemical manipulation has reached a great way to perfection, the precious metals are separated by nitric acid and other agents, but the processes are far too expensive and tedious to admit of being used upon a large scale.

For the purposes of rendering gold containing foreign metals sufficiently pure for the operations of coinage, Mr. Warrington has recently described a process by which fused gold is treated with black oxide of copper, with a view to oxidizing those metals which render gold too brittle for manufacture into coin. Mr. Warrington proposes to add to fused gold, which is found to be alloyed with tin, antimony, and arsenic, 10 per cent. of its weight of the black oxide of copper, which, not being fusible, is capable of being stirred up with the fused mass of gold, just as sand may be stirred up with mercury, but with this great advantage, that the oxide of copper contains oxygen, with which it parts readily to oxidize any metal having a greater affinity for oxygen than itself. The metals, once oxidized, become lighter than the fused metal, and mixing mechanically, or combining chemically with the black oxide of copper, float to the surface and are removed. In the execution of Mr. Warrington's proposition, it is imperative to use crucibles free from reducing agents, such as carbon, and it is found that half an hour is sufficient time to allow the contact of the oxide of copper with the fused gold.

It has been generally stated by those supposed to be acquainted with the subject, that gold containing tin, antimony, and arsenic is so brittle as to render it wholly unfit for coinage. This requires modification, for although these metals, as well as lead, render gold so
brittle that it will readily break between the fingers, yet it is not true to say that it renders gold so brittle as to be incapable of being coined. In June and July, 1859, some brittle gold, to the extent of about 64,000 ounces, passed through the Mint. The bars were so brittle that they broke with the slightest blow from a hammer, but by special treatment the gold was cooled into the toughest coins ever produced. It may now be stated that if the system of manufacture be changed to suit the requirements of the case, gold cannot be found too brittle for the purpose of coining. This is simply a matter of fact, but the expense of coining brittle gold is undoubtedly very great; it is therefore wise that Mr. Warrington's plan should be adopted for all gold containing the volatile metals or tin, Osmandiridium does not render gold brittle. Dr. Pery and Mr. Smith have demonstrated that all metallic substances found in commerce contain traces of gold, which can be separated by carefully conducted chemical processes, and it is found that silver is peculiarly liable to be in alloy with gold, and gold with silver; hence a process of refining which shall effect the separation of as little as one-hundredth part of gold from its mass of silver, is a matter of the utmost commercial importance.

It is with regret that it is stated that the refineries of London are conducted with such secrecy as to render a full description of any one of them impossible, while the ignorance which will induce the proprietors of these establishments to attempt such quietude is much to be pitied, for, except so far as regards details of interior arrangement, their processes are as well known and understood as it is possible for any manufacture to be.

In Paris, the London refineries are known to use the "French process," the plan adopted is founded on the fact, that at a high temperature sulphuric acid parts with one equivalent of its oxygen to oxidize an atom of a metal, while the atom of oxide so formed at once combines with another atom of sulphuric acid to form a sulphate. The atom of sulphuric acid which has parted with its atom of oxygen passes off as gaseous sulphurous acid.

If mercury be boiled with sulphuric acid, (commonly called oil of vitriol,) it is found that it entirely loses its metallic existence, and assumes the form of a dense white salt. This change takes place at the expense of the sulphuric acid, and is shown by the following equation.

\[ Hg + SO_3 \rightarrow HgSO_3 \]

If now the mind substitutes silver for mercury, and so writes Ag instead of Hg, the whole matter will be understood. The silver is dissolved in sulphuric acid just as sugar would in water, and in this fact we have a valuable means of separating it from gold. If for a moment one imagines a mass of silver alloyed with gold to be represented by a piece of sponge filled with water and frozen, it is well known that if the mass be warm the ice is melted, and in the form of water filters from the sponge; just so, if a mass of the alloy of the precious metals be boiled in sulphuric acid, the silver is dissolved or washed away, leaving the gold in the form of a sponge, which, as it becomes exposed to the bubbling of the acid, is detached and falls to the bottom of the vessel in which it is boiled.

If by assay the silver to be refined is found to be very rich in gold, it is better to fuse the mass with more silver, so as to produce a mass containing at least 3 of silver to 1 of gold, and this alloy, in its fluid state, should be poured into cold water, by which the falling stream is suddenly chilled, and the particles become what is technically called "granulated." The stream should fall some distance (not less than 2 feet) through the air before it reaches the water, that the copper (if any be present) may be as much as possible oxidized, with a view to saving sulphuric acid.

In all cases the alloyed metals should be granulated, because the extended surface of metal presented to the hot acid saves much time.

Silver containing less than \( \frac{1}{200} \) part of its weight of gold is found not to pay for separation, but any which contains this amount or more is treated as follows:

- Vessels of platinum were formerly used, and were deemed indispensable, but experiment has proved that these may be safely replaced by cast-iron vessels; in both cases the boilers or retorts are provided with tubes passing from the top into chambers which receive the acid gases and vapors.

The platinum vessels used by Mr. Mathison and subsequently by Messrs. Rothschild for many years are now out of use, but as sketches of the vessels actually used cannot be obtained, it is deemed wise to give a sketch of the platinum vessels, which weigh 323-40 toy ounces, and contain, if filled to the neck, 8 gallons of water. A the renot or boiler; B the head, provided with a tube of platinum, c to which is joined at the time of use a long tube of lead. C is a tube terminating on the shoulder of the boiler, and provided with a lid, and is of service to allow of the occasional stirring of the silver during solution, and of the addition of the small quantity of acid at the termination of the chemical action. The vessels became much coated with gold, which was removed with difficulty and at great risk of attacking the platinum. The sketches (figs. 583, 584, and 585) are 1 in. to a foot.
According to convenience and requirements, the retort or boilers may be multiplied as to number, but about 5 or 6 would seem to be a convenient set for operations. Independently of the smaller prime cost of cast-iron retorts or boilers, (now used in place of platinum,) there is the advantage of being able to use acid which is not free from impurities, because the cost of the retorts is practically not worth consideration, if taken in relation to the extra price which must be paid for pure acid. Besides these facts, it is found that owing to some influence (is it chemical or catalytic?) which the iron exerts, less acid is required to be used in proportion to the precious metals than was used when platinum vessels were believed to be necessary.

A charge for one boiler varies from 1130 to 1300 troy ounces of the granulated mixed precious metals, and is heated with about twice or twice and a half times its weight of sulphuric acid of sp. gr. 1:7047. The heat is gradually raised until effervescence takes place, and it is then regulated with care, while at last, the temperature is raised nearly to the boiling point. As in the case of mercury so in the case of silver, it is better not to rise quite to the boiling point, else sulphuric acid distils off with the escaping sulphurous acid. According to the care with which the granulating has been effected, each charge is heated from 3 to 4 hours. When the elimination of sulphurous acid ceases the operation is known to be terminated, and chemical examination shows that exactly equivalent quantities of sulphate of silver and sulphate of copper are formed to account for the sulphuric acid. In practice the sulphurous acid is frequently lost, although in all refineries it should be used for the recombination of sulphuric acid.

Leading from the top of the boiler or retort is an horizontal leaden tube from 8 to 10 yards long, terminating in a leaden chamber, in which sulphuric acid and sulphurous acids accumulate with some sulphate of silver mechanically carried over by the violence of the chemical action. It is found that the acid which accumulates in this leaden chamber has a sp. gr. of from 1:3804 to 1:4493. The reduced strength of the acid from 1:7047 to this point is readily understood if the fact be remembered that sulphuric acid is really a compound of anhydrous sulphuric acid and water, and that only the anhydrous sulphuric acid is concerned, although the water performs the friendly part of leading it into action on the silver; the action having commenced, the water is done with, and passes off with the sulphurous acid as it is eliminated; but independently of this cause, it is found that sulphuric acid, by boiling, parts with water, and concentrates itself, until by and by the anhydrous acid itself distills off, and when this is seen, it is at once known that the operation is carried rather too far. When the action has quite terminated, it is customary to add to each boiler or retort from 60 to 80 troy ounces of sulphuric acid of sp. gr. 1:6556, procured from the liquor which has deposited sulphate of copper, (presently described,) then to pour the whole into a leaden boiler, and boil it for a few minutes, then withdraw the fire, and allow to stand for half an hour, during which time the gold is precipitated. The object in adding this amount of sulphuric acid is to form a clear solution, that the gold may be enabled to settle to the bottom; water could not be added, because it would probably cause an explosion by the heat evolved in its combination, and because sulphate of silver is not very soluble in water, while it is soluble to a very large extent in hot sulphuric acid. At the end of half an hour the clear liquor, containing in solution the silver and copper as sulphates, is decanted and mixed with so much water as shall reduce it to a sp. gr. of from 1:2080 to 1:2605, and well stirred. Copper plates are then introduced, while the solution is kept hot or boiling by a jet of steam.

The silver salt is decomposed by the copper plates, and the copper passes into solution as sulphate of copper, so that at the end of the precipitation the solution contains the copper of the original alloy, as well as the copper which has been used to precipitate the silver. The silver precipitates or falls to the bottom in a finely divided or spongy form, and it is commonly thought that the whole of the silver is thrown down when a portion of the solu-
tion is not rendered turbid by a solution of chloride of sodium; but in the presence of a strongly acid solution this test is not to be relied on for minute quantities; therefore, in some refineries, the solution is allowed to rest for days together in leaden cisterns in which copper plates are placed, so that by these means the last traces of silver are obtained.

If the amount of gold be very minute, the original solution is well stirred and then allowed to settle for some time, when finely divided gold, mechanically mixed with crystals of sulphate of silver and crystals of sulphate of copper, is found at the bottom. This deposit is boiled with water, and is then transferred to a vessel in which it is kept hot, and is brought into contact with suspended copper plates, by which the silver is rendered metallic, and falling to the bottom of the vessel, mixed with the gold. The mixed precipitate of silver and gold is then dried, melted, and granulated, and treated with sulphuric acid, as in the process already described. By this extra process the gold becomes concentrated by the removal of the silver, and is then thrown down in larger and more easily collected particles. When the gold is finely divided and precipitates slowly, the following plan is sometimes adopted:—

The whole precipitate containing finely-divided gold mixed with sulphate of silver, is washed well with warm water, and left to rest. The sulphate of silver is dissolved, but the gold settles to the bottom of the vessel, but is still mixed with a minute quantity of sulphate of silver. It is then dried and placed in the retort or boiler of cast iron, and boiled with sulphuric acid; this boiling is twice repeated, and at last a very diluted solution of sulphate of silver is obtained; but by the boiling the gold has assumed a form which enables it to precipitate rapidly; in fact, the flocculent sponge becomes a mass of dense particles, which fall readily to the bottom, are collected and well washed, to free them from silver, and are then dried ready for melting.

The solution of sulphate of silver is evaporated in leaden vessels by the agency of steam until it becomes saturated, and is then allowed to stand for an hour, that all the gold may separate, and is then drawn off either by a tap placed about half an inch from the bottom of the vessel, or by a siphon, and is then treated with copper plates as already detailed.

In all cases the precipitated sponge silver is carefully washed to free it from sulphate of copper, and dried by heat or by hydraulic pressure; but if dried by pressure the masses obtained are found to contain from 8 to 10 per cent. of water, and are therefore dried by gentle heat to avoid the breaking up of the masses, from the sudden formation of steam, as well as to save the chance of destroying the pot of Picardy clay in which the silver is melted when it has been dried.

After melting, the silver is found to retain traces of gold, which are so minute as to be overlooked, since the cost of recovery would exceed the value of the gold to be recovered; but the silver is found to be alloyed with from 5 to 6 thousandths of its weight of copper, which appears to be left in the form of sulphate, notwithstanding the washings to which the silver has been subjected. It is practically impossible to wash away the last traces of sulphate of copper. This small amount of copper is of little importance, since it amounts to but 5 parts of copper alloyed with 205 parts of silver, yet this may be removed by fusion and treatment with nitrate of potassa.

During the whole process, even if copper be not present in the original mass of metal to be refined, it is to be observed that copper plates are used for precipitating the silver; therefore sulphate of copper is found in considerable quantities, and as this salt has a high commercial value as giving the base for many colors used in painting and paper-hangings, as well as for agricultural purposes, it becomes desirable to obtain this salt in a salable form. The solution is therefore evaporated to a sp. gr. of 1.3804, and allowed to cool, when crystals deposit; but since sulphate of copper deposited from strongly acid solutions is mixed with the anhydrous salt, the whole mass of crystals is redissolved in warm water, and allowed to stand in leaden vessels about 6 ft. long, 3 ft. deep, and 3 ft. wide, that the crystals may deposit slowly, as slow formation produces large crystals, which are more easily collected. The sulphate of copper is represented by CuSO₄.5H₂O. The mother liquors are evaporated and returned to the works, being in fact free sulphuric acid, with a small amount of sulphate of copper in solution. The parts of the hydraulic presses which come in contact with the silver at the time of pressing, are coated with a compound of tin and lead, hardened by mixture with antimony. Cast iron is very little attacked by concentrated sulphuric acid, but it is necessary to avoid wrought iron in any shape, and copper vessels would of course be rapidly destroyed.

The floors should be covered with lead of tolerable thickness. The melting pots used in France are made of Picardy clay, and hold from 2260 to 2600 Troy ounces of silver. The pots cost from 4d. to 6d. each, and if dried and used with care, very seldom crack or break.

The total cost of refining silver in Paris, inclusive of the loss by melting, is stated to be 15 centimes for 32 Troy ounces; but it must be understood that the loss of silver by melting is absolutely very minute, because the fluxes are swept, and the sweepings so obtained are made to yield the silver which has been volatilized, while the pots, &c., are ground and made to yield their absorbed silver.

In the event of the mass containing much copper and little silver, it is usual to granulate
RHODIUM.

the mass and roast the granulated particles to oxidize the copper; the oxide of copper is then dissolved out by diluted sulphuric acid, and the remaining mass of silver, with a smaller amount of copper, is treated in the ordinary way.

If the gold contains platinum, it is found that it is apt to retain from 4 to 5 per cent. of silver, which must be separated by mixing the precipitated gold with about a fourth of its weight of anhydrous sulphate of soda, (which is preferred to sulphate of potassa, on account of its greater solubility in water,) and to moisten this mass with concentrated sulphuric acid, using about 6 or 7 parts of acid to every 10 parts of sulphate of soda. The moistened mass is then heated till sulphuric acid ceases to distil off, and the heat is then raised till the whole mass melts; and by extracting the sulphate of silver and sulphate of soda the gold will be found to contain 99-90 parts of gold in 100,000 parts; but if the process be repeated, the gold is obtained of a purity of 99-95.

When the silver has been removed, the gold is fused with nitre, which oxidizes and removes the platinum; but the potash salt formed is found to contain gold, so that the gold and platinum are obtained from the potash salt mixed with fused nitre by the process of cupellation, for which see ASSAY.—G. F. A.

RHODIUM. The following remarks from a recent paper by Deville and Debry, "On some properties of the so-called platinum metals," are full of interest. These chemists prepare rhodium by fusing platinum residues with an equal weight of lead and twice its weight of litharge. When the crucible has attained a bright red heat, and the litharge is thoroughly liquid, the crucible is shaken once or twice, and is then allowed to cool slowly. The button of lead, which contains all the metals in the residue less oxidized lead, is treated with nitric acid, diluted with an equal volume of water, which removes besides the lead the copper and the palladium. The insoluble powder which remains is mixed with five times its weight of binoxide of barium, weighed exactly, and is heated to redness in a clay crucible for one or two hours. After this it is first treated with water, and then with aqua regia to remove the osmic acid. When the liquor has lost all smell, sufficient sulphuric acid is added to precipitate the baryta. It is then boiled, filtered, and evaporated, first adding to it a little nitric acid and then a great excess of sal ammoniac. The evaporation is carried to dryness at 212°, and the residuum is washed with a concentrated solution of sal ammoniac, which removes all the rhodium. When the washings are no longer colored, the liquor is evaporated with a great excess of nitric acid, which destroys the sal ammoniac, and when only the salt of rhodium is left, the evaporation is finished in a porcelain crucible. The rhodium salt is now moistened with hydrox sulphide of ammonia, mixed with three or four times its weight of sulphur, and the crucible is heated to bright redness, after which metallic rhodium is left in the crucible. So obtained rhodium may be considered almost pure, after it has been boiled for some time, first in aqua regia, and then in concentrated sulphuric acid. To obtain it perfectly pure it must be melted with four times its weight of zinc. The alloy is treated with concentrated hydrochloric acid, which dissolves most of the zinc, but leaves a crystalline matter which is really an alloy of rhodium and zinc in definite proportions. This is dissolved in aqua regia, and the solution is treated with ammonia until the precipitate first formed is redissolved. The solution is boiled and evaporated, by which is obtained the yellow salt, or chlorid of rhodium. This is purified by repeated crystallization, and then calcined with a little sulphur, by which means rhodium is procured absolutely pure.

Rhodium melts less easily than platinum, so much so that the same fire which will liquefy 300 grammes of platinum will only melt 40 or 50 grammes of rhodium. It is not volatilized, but it oxidizes on the surface like palladium. Less white and lustrous than silver, it has about the same appearance as aluminum. When perfectly pure it is ductile and malleable, at least after fusion. Its density is 12.1.

The alloys of rhodium, those at least which have been examined, are true chemical combinations, as is shown by the high temperature developed at the moment of their formation. The alloy with zinc already described resists the action of muriatic acid, but in contact with air and the acid there is soon a well-marked rose coloration which reveals an oxidation of the two metals under the double influence of the air and acid. The alloy with tin is crystallized, black, brilliant, and fusible at a very high temperature.

RIFLES. RIFLED ORDNANCE AND REVOLVERS.—Under the head of Fire-Arms, vol. i., in addition to the general description of the manufacture of the ordinary musket barrel and the twisted barrel, with that of gun locks of various kinds, there is an account of the mode adopted for rifling barrels, and of the methods in use at the Royal Manufactory at Enfield. Beyond this, the cavallie à tige, the Minit rifle, with the needle musket, or zündendegen, of the Prussians, were severally noticed; and some information given respecting the more recent Enfield rifle. So many and so important have been the improvements which have been introduced that it is necessary to return, somewhat more fully, to the consideration of this subject. Fire-arms are rifled to give rotation to the projectile round its axis of motion, in order to insure a regular and steady flight. The only process known, and of doing this, hitherto adopted, has been to make the barrel of a fire-arm of such a shape in its interior, that the projectile, while being propelled from the breach to the muzzle, may receive a rotatory, combined with a forward, motion.
RIFLES.

Enfield Rifle.—The dimensions, &c., of the long Enfield is given in the article already referred to. The barrel of the short Enfield is only 2 ft. 9 in. in length.

The material for the barrels of the arms made at the Government works is brought to the factory in slabs, half an inch thick, and 12 in. long by 4 in. broad. These slabs of iron are carefully forged, to insure the crossing of the fibres of the iron. They are heated, and first bent into a tubular form; they are then heated again, and while white hot, passed between iron rollers, which weld the joining down the middle, and at the same time lengthen the tube nearly three inches. This heating is several times repeated, and the processes of rolling continued until the barrel assumes the form of a rod, about 4 ft. long, having a bore down the centre about \( \frac{1}{4} \) of an inch in diameter.

The muzzles are then cut off, the "butts" made up, and the process of welding on the nipple lump is begun. This operation requires much care, and it is executed with great quickness and skill by the trained workmen. The barrels pass from the smithy to the boring department. The barrels are arranged horizontally, and the first-sized bore is drawn upward from the breech to the muzzle. The second boring is effected with rapidity; but the third slowly; and after the fourth boring the barrel is finished to within the \( \frac{1}{1000} \) of an inch of its proper diameter. The outside is ground down to its service size, and the barrel is straightened; it is then tested by a proof-charge of 1 oz. of powder and 1 ball. The next step is to fit the nipple-screw, nipple, and breech-pin. The barrel is then bored for the fifth time, and it passes to the finishing shop. In rifling the Enfield, each groove is cut separately, the bit being drawn from the muzzle to the breech. The depth of the rifling is \( 0.05 \) at the muzzle, and \( 0.13 \) at the breech, and the width of each groove is \( \frac{1}{16} \) of an inch. After rifling the barrel is again proved, with half an ounce of powder and a single ball. It is then sighted, trimmed off, milled, levelled, browned, gauged, and, at last, finished so perfectly, that the steel gauge of \( \frac{1}{37} \) of an inch passes freely through, while that of \( \frac{1}{39} \) will not enter the muzzle.

The system of rifling by grooves is the plan which has been generally employed, and many experiments with different numbers of grooves, some of varying depths, being deeper at the breech, and with different turns, some increasing towards the muzzle, have been tried, and thought advantageous, at various times. The Enfield rifle has three grooves, with a pitch of 6 ft. 6 in., so that the bullet receives half a turn round its axis while moving through the barrel, the length of which is 3 ft. 8 in. The bullet is cylindro-conehoidal; it is wrapped in paper, and made of such a diameter as to pass easily down the barrel. It requires very pure lead, to allow of its being properly expanded, or "upset," by the explosion, and is driven partly against the original portions of the bore, called the lands, and partly in the form of raised ribs, is forced into the grooves, whose spiral shape gives the required rotation. The Enfield bullet is shown in the annexed figure. It is conical in shape, and has its back end recessed for the insertion of a box-wood plug. This plug, driven forward at the first shock of the explosion of gunpowder, expands the lead until it fills the grooves at the breech. (fig. 586.)

The prime cost of a finished Enfield rifle is stated to be about \( \£ 2.5 \); and from 1,500 to 1,800 rifles per week are at present made at the Enfield rifle factory.

Whitworth's Rifle.—This fire-arm, and the principles on which it is constructed, cannot be better described than by adopting to a great extent the words of the inventor:—In the system of rifling which I have adopted, the interior of the barrel is hexagonal, and instead of consisting partly of non-effective lands, and partly of grooves, consists of effective rifling surfaces. The angular corners of the hexagon are always rounded, as shown in section, fig. 588, which shows a cylindrical bullet in a hexagonal barrel. The hexagonal bullet, which is preferred to the cylindrical one, although either may be used, is shown in fig. 587. Supposing, however, that a bullet of a cylindrical shape is fired, when it begins to expand it is driven into the recesses of the hexagon, as shown in fig. 588. It thus adapts itself to the curves of the spiral; and the inclined sides of the hexagon offering no direct resistance, expansion is easily effected. With all expanding bullets proper powder must be used. In many cases this kind of bullet has failed, owing to the use of a slowly-igniting powder, which is desirable for a hard metal projectile, as it causes less strain upon the piece; but is unsuitable with a soft metal expanding projectile, for which a quickly-igniting powder is absolutely requisite to insure a complete expansion, which will fill the bore; unless this is
done the gases rush past the bullet, between it and the barrel, and the latter becomes foul, the bullet is distorted, and the shooting must be bad. If the projectile be made of the same hexagonal shape externally, as the bore of the barrel internally, that is, with a mechanical fit, metals of all degrees of hardness, from lead, or lead and tin, up to hardened steel, may be employed, and slowly-igniting powder, like that of the service, may be used. As we have already stated, the Enfield rifle has one turn in 6 ft. 6 in.; that is, the bullet rotates once on its axis, in passing over this space. This moderate degree of rotation, according to Mr. Whitworth, only admits of short projectiles being used, as long ones turn over on issuing from the barrel; and at long ranges, the short ones becomes very cloudy. With the hexagonal barrel much quicker turns are used; and "I can fire projectiles of any required length, as, with the quickest that may be desirable, they do not ‘strip.’" I made a short barrel, with one turn in the inch (simply to try the effect of an extreme velocity of rotation) and found that I could fire from it mechanically-lifting projectiles, made of an alloy of lead and tin; and with a charge of 53 grains of powder they penetrated through 7 inches of elm planks.

"For an ordinary military barrel 39 inches long, I proposed a 45-inch bore, with one turn in 20 inches, which is, in my opinion, the best for this length. The rotation is sufficient, with a bullet of the requisite specific gravity, for a range of 2,000 yards. The gun responds to every increase of charge, by giving better elevation, from the service charge of 70 grains up to 120 grains; this latter charge is the largest that can be effectually consumed, and the recoil then becomes more than the shoulder can conveniently bear with the weight of the service musket."

The advocates of the slow turn of one in 6 ft. 6 in., consider that a quick turn causes so much friction as to impede the progress of the ball to an injurious, and sometimes dangerous, degree, and to produce loss of elevation and range; but Mr. Whitworth's experiments show the contrary to be the case. The effect of too quick a turn, as to friction, is felt in the greatest degree when the projectile has attained its highest velocity in the barrel, that is at the muzzle, and is felt in the least degree when the projectile is beginning to move, at the breech. The great strain put upon a gun at the instant of explosion is due, not to the resistance of friction, but to the vir inertiæ of the projectile which has to be overcome. In a long barrel with an extremely quick turn, the resistance offered to the progress of the projectile as it is urged forward becomes very great at the muzzle, and although moderate charges give good results, the rifle will not respond to increased charges by giving better elevation. If the barrel be cut shorter, an increase of charge then improves the elevation.

**Rifled Ordnance.** See Artillery. Whitworth's system of rifling is equally applicable to ordnance of all sizes, the principle of construction is simple, and the extent of bearing afforded by the rifling surfaces provides ample for the wear of the interior of the gun; any requisite allowance for windage may be made at the same time that the projectile is kept concentric with the bore. We have not space to enter on any examination of the rifled ordnance manufactured by Mr. Whitworth, which is in principle the same as the rifle which we have briefly described. The extraordinary results obtained in the trials of Whitworth's guns have been so remarkable, that as a matter of curious history it appears important to preserve a statement of these trials, as made at Southport, which were witnessed by many of the most eminent authorities.

Our space will not admit of our giving tables of all the experiments made; we have, therefore, chosen those which give the best and most interesting results. We have in each table given the distance of every shot fired in the series or group forming the particular experiment. In some cases average distances are calculated from the several points of the group of shots fired, and are taken longitudinally and laterally. This is, in fact, applying to the horizontal area in which the shots fell the same principles on which the "figure of merit" is determined on the vertical targets at the Hythe School of Musketry. This method of calculation is the most accurate, for, as the gun was always laid for the line of fire, and no alteration was made in its direction during the firing of a particular group, a certain amount of deviation would be given to all the shots by the wind. Therefore, the closer the shots lay, the better was the shooting, without regard to the general deviation from the line of fire, which might be greater or less according to the direction and force of the wind.

After this digression we return again to the Rifles. A professional writer, well qualified to judge of the matter on which he wrote, has made some striking remarks on the Whitworth rifle in the *Mechanics' Magazine*. After pointing out the small importance of a high prime cost in the case of so durable a weapon as the rifle in question, he refers to the strength of the metal used.

In illustration of its great strength, this fact is quoted: Mr. Whitworth put into a rifle barrel, one inch in diameter at the breech, with a bore of 0.475 inch; a bullet 18 inches long, as tightly as it could be driven home upon the charge. It was fired with an ordinary charge of powder, and the leaden plug being expanded by the explosion remained in the barrel, the gases generated by the gunpowder all passing out through the touch-hole.
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With such strength great durability must of necessity co-exist, unless the quick turn of the rifling should tend to its rapid deterioration. But this is not the case, Mr. Longridge’s elaborate investigations having proved that the amount of the force expanded upon the rifling of the Whitworth rifle scarcely exceeds two per cent. of the total force of the powder.

Table of Experiments.

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Perhaps the most remarkable testimony which has been borne to the merits of this rifle is that of General Hay, the director of musketry instruction at Hythe. After admitting the superiority of the Whitworth to the Enfield in point of accuracy, General Hay said there was a peculiarity about the Whitworth small-bore rifles which no other similar arms had yet produced—they not only gave greater accuracy of firing, but treble power of penetration. For special purposes, any description of bullet could be used, from lead to steel. The Whitworth rifle, with a bullet one-tenth of an inch, penetrated 33 planks, whereas the Enfield rifle, with which a soft bullet was necessary, only penetrated 12 planks. He had found that at a range of 800 yards, the velocity added to the hardened bullet gave a power of penetration in the proportion of 17 to 1 in favor of the Whitworth rifle. This enormous penetration is of the highest importance in a military weapon, in firing through gables, sandbags, and other artificial defences. Mr. Bidder, President of the Institution of Civil Engineers, says, the Whitworth small-bore rifle, fired with common sporting powder, would never fail so as to render loading difficult. He had himself fired 100 rounds one day, 60 rounds the next, then 40 rounds, and so on, and left the gun without being cleaned for ten days, when it fired as well as it did on the first day. The words of Mr. Whitworth as to the application of his
principle to the Enfield weapon must be quoted in answer to the objections of cost, &c., urged against it. "With regard to the cost of my rifled musket, which has been stated to be an impediment in the way of its adoption for the service, I may state that there would be no difficulty in adapting the machinery and plant already in operation at Enfield, or any requisite portion of it, for making rifles on my system. The change would not cause an increase in the manufacturing expenses; and, supposing the quality of the workmanship and the materials to remain the same, the advantages arising from the use of my bore and turn, and hard metal projectiles, would double the efficiency of the rifle without increasing the cost."

Amongst arms requiring some notice from us, the more remarkable, as involving some excellence in construction, or peculiarity in principle, are the following:

Colt's Repeating Rifle.—This weapon is constructed mainly on the principle which was introduced by Colonel Colt, in his "revolvers," to be noticed presently. The Secretary of War of the United States reports as follows on this arm, which is shown in fig. 589, and in section fig. 590. Fig. 591 is a vertical section of the revolving barrels, and fig. 592 the wiping rod.

"The only conclusive test of the excellence of the arms for army purposes is to be found in the trial of them by troops in actual service. Colonel Colt's arms have undergone this test, and the result will be found in some measure, by reports of General Harney and Captain Marcy, who used them in Florida against the Indians. These reports relate only to the rifle, but are clear and satisfactory. * * * A board of officers recently assembled to consider the best mode of arming our cavalry, made a report, showing the present appreciation of the arm by officers of the army standing deservedly high for their services, experience, and intelligence."

In its internal construction this rifle differs in some respects from the pistols and early revolving rifles. The catch which causes the breech cylinder to revolve, instead of acting against ratchet teeth, and on the cylinder itself, works in teeth cut on the circumference of the cylinder end of the base-pin, in such a manner, that the base-pin rotates with the cylinder itself, being locked by a small mortise in the cylinder; and the stop-bolt gears into corresponding notches, also cut in the end of the base-pin, and thus locks it when required. This is an improvement in the arrangement of these weapons, and by a simple arrangement, the small spring catch, which, by means of a circular groove in the front end of the base-pin, keeps it in place, is immediately released by pressing on a small stud, and the cylinder can be instantaneously removed or replaced. Instead of the pin, which, in the pistol, is used to let the hammer down on, when carrying it, a small recess is cut between each nipple, in the cylinder itself, into which the hammer fits when let down, and makes security doubly secure.

The rifle is provided with two sights; the ordinary leaf sight usually employed is also provided. The hinder sight is adjustable to suit long or varying ranges, and the front sight is that known as the bead sight, which consists of a small steel needle, with a little head upon it, like the head of an ordinary pin inclosed in a steel tube. In aiming with this sight, the eye is directed through a minute hole in the sliding piece of the hindcr sight, to the small bead in the tube, which bead should cover the mark aimed at; and this sight affords great accuracy in shooting. The wiping rod, which occupies the position usually allotted to the ramrod in muzzle loaders, is ingeniously constructed so as to admit of being lengthened. In its interior, which is hollow, slides a slight steel rod, in end of which a screw thread is cut; on drawing out the rod, a turn or so of the hand in one direction enables this steel rod to be drawn out to a length, as nearly as possible that of the outer case, and a few turns in the contrary direction fastens it firmly in its place; thus enabling it to be used with as much facility as if it were solid. When done with, the reversal of the former motions enables the rod to be returned to its original dimensions, and it can then be returned to its place. This weapon has a real business-like serviceable appearance, and its weight varies, according to the length of the barrel, from 8 lb. to 10 lb. each, with five and six shots.

Colonel Colt has introduced a new shot-gun which is adapted for being loaded alternately with shot and ball. This is adapted for the colonist, enabling him to use the gun as an ordinary sporting weapon for birds, &c., or for more deadly purposes. The ball for Colt's rifle is shown by figs. 594, 595.

Lancaster's Elliptic Rifle.—So called, although the elliptical rifle is very old. The bore in this rifle is slightly oblate; the twist found by experience, to be most advantageous is one turn in 52 inches, the approved diameter of the bore 498 inches, the length of the barrel being 52 inches. An eccentricity of 01 inch in half an inch is found sufficient to make the bullet spin on its axis to the extreme verge of its flight. The length of the bullet found to answer best with these rifles is 23 diameters in length, with a windage of four or five thousandths of an inch.

Major Nathall's Rifle.—In the ordinary mode of grooving rifles, sharp angles are left between the groove and "land," (those parts of the smooth bore left in their original state after the process of grooving has been completed.) These create friction with the projectile, both in loading and discharging. Major Nathall removes these objections by rounding off the "lands" into the grooves, that is, making them a series of convex and con-
curves, the bore assuming a beautiful appearance to the eye, for the smoothness and evenness with which the lands and grooves blend into each other.
There are also General Boileau's rifle, and some others, which our space will not admit of our noticing.

**Breech-loading Rifles** have been introduced, and they prove so satisfactory that the principle of breech-loading is applied to ordinary fowling pieces. Prince's breech-loader has been highly recommended. In this rifle, fig. 596, the barrel has attached to it a lever with a knob at its end, kept in its place and locked by a little bolt attached to the bore of the guard. In order to load, the stock being firmly grasped under the right arm, the catch is released, and the knob attached to the lever is drawn to the right, and almost simultaneously pushed forward. The lever being firmly connected with the breech end of the barrel, the whole of the barrel is thus slipped forward in the stock, to the extent of about three inches, disclosing a steel cone, provided on either side with inclined planes, forming a segment of a screw, and locking tightly into slots at the breech end of the barrel. The cartridge is dropped into the open space at the extremity of the cone, the lever is depressed, pull backward, and then pushed into its place. The barrel and cone are thus tightly locked together, and until they are in this position the gun cannot possibly be fired. It is therefore obvious, that in strength and security this rifle is not inferior to any. At a trial at Hythe, Mr. Prince fired 120 rounds in less than eighteen minutes, showing the rapidity of loading which this weapon admits of. The rifling preferred by the inventor is a five-grooved bore, rather deeply cut, the twist being three quarters of a turn in three feet. The London gunmakers have certified to the great merits of Prince's breech-loading rifle.

Prince's cartridge is an ingenious invention; it can be used either with a muzzle or with a breech-loader. The cartridge is made of gun-paper, produced in the manner described for making gun-cotton. The spark fires this with the powder, and if the paper is pure there is no ash left from its combustion. Mr. Prince is bringing out a new breech-loading rifle which is simpler than any yet produced. His practical experience in such matters, extending over more than a quarter of a century, combined with the success he has already attained, causes any fresh arm emanating from him to be regarded with considerable attention. The breech is opened by a half turn of a lever, and closed by a corresponding movement. Either common ammunition or a flask can be used in loading. The barrel is a fixture; a chamber being attached to the breech end, so that existing muzzle-loaders may be readily converted. For cavalry a simple addition is made to the arm, so that the caps are placed on the nipple in the act of loading.

Terry's Breech-loading Rifle differs from Prince's in having the barrel fixed. There is an opening at the base of the breech, which being lifted by a lever discloses a receptacle for the cartridge.

Mr. Wesley Richards, Mr. James Letch, and some others have introduced breech-loading rifles. Of the former, Colonel Wilford says: "The weapon manufactured by Mr. Westley Richards is a perfect wonder. I saw a small carbine, weighing only 5½ lbs., fire better at 800 yards than the long Enfield."

In the rifle by Letch the opening for the admission of the charge is in front of the chamber; consequently the shooter has all the security that the solidity of the breech can impart.

**Revolvers or Repeating Pistols.**—The fame attached to Colt's revolvers, fig. 595, renders them so well known as to require but little introduction. Although the invention of revolvers of course cannot be ascribed to Colonel Colt, their adaptation to modern requirements, and their general use, are undoubtedly due to his extreme energy, perseverance, and skill, and to him, therefore, every credit ought to be given. This make is now extensively used in the United States, and indeed in almost every corner of the world, and seem not to lose favor anywhere. In Turkey, Egypt, Brazil, Peru, Spain, Holland, Prussia, Russia, Italy, and Chili, as well as the United States, and our own country, they have been and are extensively used and approved; and we are given to understand that 40,000 of them have been supplied to our authorities, and have been served out and used in the Baltic, in the Crimea, in China, and in India, with the utmost effect. The shooting with Colt's arms is highly
satisfactory. With Colt's revolver you can make first-rate shooting, and be perfectly satisfied with its action. As a proof that it is not liable to get out of repair, we need only state that the American Board of Ordnance had a holster pistol fired 1200 times, and a belt pistol 1500 times, without the slightest derangement. The penetration of the first named was through 7 inches of board, and of the second through 6 inches.

The barrel is rifle-bored. The lever ramrod renders wadding or patch unnecessary, and secures the charge against moisture, or becoming loose by rough handling, or hard riding. The hammer, when at full cock, forms the sight by which to take aim, and is readily raised at full cock by the thumb, with one hand. It has been tested by long and actual experience, that Colt's arrangement is superior to those weapons in which the hammer is raised by pulling the trigger, where in addition to the great danger from accidental discharge, the strength of the pull necessary for cocking, interferes with the correctness of aim, which is of so much importance. A very effectual provision is made to prevent the accidental discharge of this pistol whilst being carried in the holster, pocket, or belt. Between each nipple (the position of which secures the caps in their places) is a small pin, and the point of the hammer has a corresponding notch; so that if the hammer be lowered on the pin, the cylinder is prevented from revolving, and the hammer is not in contact with the percussion cap, so that, even if the hammer be struck violently by accident, it cannot explode the cap.

The movements of the revolving chamber and hammer are ingeniously arranged and combined. The breech, containing six cylindrical cells for holding the powder and ball, moves one sixth of a revolution at a time; it can only be fixed when the chamber and the barrel are in a direct line. The base of the cylinder being cut externally into a circular ratchet of six teeth, (the lever which moves the ratchet being attached to the hammer;) as the hammer is raised in the act of cocking, the cylinder is made to revolve, and to revolve in one direction only; while the hammer is falling the chamber is firmly held in position by a lever fitted for the purpose; when the hammer is raised the lever is removed, and the chamber is released. So long as the hammer remains at half cock, the chamber is free and can be loaded at pleasure. Revolvers by Daw, by Adams and Dean, and others, have been introduced. They are all so similar in principle that they need not be described.

ROLLING MILLS. These useful aids to many of our metallurgical processes appear to have been introduced to this country in the seventeenth century; but it was not until 1784, when Mr. Cort patented "a new mode and art of shingling, welding, and manufacturing iron and steel into bars, plates, &c.," that much attention was directed to the value of the rolling mill.

Fig. 597 is a front view of a pair of rollers, used in the manufacture of iron in connection with the puddling furnace. They are about 4 feet long, divided into 4 parts, the largest being about 20 inches in diameter. That portion of the upper roller under which the metal is first passed, is cut in a deep and irregular manner, resembling that chiseling in stone called moulder work, that it may the more easily get hold of and compress the metal when almost in a fluid state. The plate is next passed under the cross-cut portion of the roller, and successively through the flat sections. The lower roller, it will be observed, is formed with raised collars at intervals, to keep the metal in its proper course. The rollers are connected by cog-wheels placed upon their axes; upon the lowermost of these, works also the wheel by means of which the revolution is communicated. The cheeks are of cast iron, very massive, that they may bear the violent usage to which they are subjected.

We cannot go into the numerous purposes to which rolling mills of this kind are applied; a few may be mentioned.

The practice of "slitting" sheets of metal into light rods, either for the use of the wire-drawers or of nail-makers, is carried out by means of two large steel rollers, channelled
RUTHERIUM.

circularly, as in fig. 508. These are so placed that the cutters or raised parts of one roller, which are exactly turned for that purpose, shall work in corresponding channels of the other roller, thus forming what may be called revolving shears, for the principle is that of clipping; so that a sheet of metal on being passed through this machinery, is separated into slips agreeing in size with the divisions of the rollers.

Rolling mills have been patented for rolling tubes for gas and other purposes. See Tubes.

For the manufacture of rails, rolling mills are also employed, fig. 599 representing a rolling mill as constructed for rolling Birkinshaw's rails. The open spaces along the middle of the figure, and which owe their figure to the moulding on the periphery of the rollers, indicate the form assumed by the iron rail as it is passed successively from the larger to the smaller apertures, till it is finished at the last.

Ruthenium. After osmium, ruthenium is the most refractory metal we are acquainted with. It requires a very extreme heat to melt the smallest quantity. When melting there is formed the oxide of ruthenium (RuO₂) which is volatilized, and which smells something like osmic acid. When removed from the flame ruthenium is blackish brown on the surface, and is brittle and hard like iridium. It is only distinctly separated from this last metal by its density, which is obviously half that of iridium. The purest ruthenium obtained weighs from 11 to 11-4.

To prepare the metal mix the osmium in fine powder with 3 parts of binoxide of barium and 1 part of nitrate of baryta, and heat them to redness in a clay crucible for an hour. The black friable mass which remains is powdered with great care and introduced into a flask in which has been previously mixed 20 parts of water and 10 parts of ordinary muriatic acid. The flask must be placed in cold water to avoid the elevation of temperature which would ensue from the violent reaction which takes place. This operation should be conducted under a good chimney to avoid the escape of the osmic acid vapor into the laboratory.

Ruthenium forms with zinc an alloy which will burn in the air; it crystallizes in hexagonal prisms. With tin there is formed an alloy RuSn, which crystallizes in cubes as beautiful in their form and lustre as crystallized bismuth.—Deville and Debay on the platinum metals.

S

SAFETY CAGE. In all collieries the men descend to their labor and are raised from the depth of the mine by the winding machinery. This may be described in general terms as a stage travelling in guides fixed to the sides of the shafts. The rapidity with which these stages are moved up or down is very great, and consequently, if any thing occurs to engage the attention of the man in charge of the winding-engine, the stage with its living load is either landed with injurious violence at the bottom of the pit, or it is carried over the pulley, and thus the lives of the men are sacrificed. The cut on the opposite page, fig. 600, shows an ingenious contrivance for obviating the blow which arises from reaching the bottom at too great a speed. a, e are platforms placed on India-rubber springs (see Caoutchouc) b, g, on the landing at the bottom of the pit; d is one of the cages which has descended, the other being supposed to be at the surface. The elasticity of these springs certainly serves to protect the men from the violence of the concussion in the event of the rope breaking, or if from any other cause they suddenly reach the bottom.

Many safety cages, so called, have been invented, the principles of which are to allow them to travel freely on their guides, so long as the rope by which they are suspended remains entire; but in the event of its breaking, the arms, levers, or catchers seize the guide-rods, and thus suddenly stop the cage. Experience has not satisfactorily confirmed the value of these arrangements.

A simple arrangement for a safety cage was published by Mr. Andrew Smith, in 1852. According to Mr. Smith's invention, the drawing rope is connected with the chain-work supporting the cage by a strong elastic tube, which gives the cage an easy motion until an
SAFETY LAMP.

accident takes place. Immediately the rope breaks, the weight of the cage forces the end of a lever against the guide-rods, which extend from top to bottom of the shaft. The following description may render the invention more intelligible:—A horizontal bar is provided with a slot at each end, through which the guide-rods pass; at the inner end of each slot is a pin, which forms the fulcrum of a lever, the shorter arm of which is towards the guide-rod. While the machinery is working properly, each lever forms as it were a link of the chain by which the cage is suspended; the bar and the connecting levers forming about an equilateral triangle. To the extremity of the longer arm of the lever are connected the rods by which the cage itself is suspended; these rods cross each other, and the cage is hooked upon the end. It will readily be understood that, while all is in order, the short arms of the lever are held back from the guide-rods, and the slot of the cross-bar is sufficiently large to admit the rise and fall of the cage without impediment; but upon the breakage of the rope the long arms of the levers are depressed, and the short arms forced, as stated, against the guide-rods, preventing the further fall of the cage. The cost of the contrivance is comparatively trifling, which is another recommendation to its use. Among the more prominent patented inventions are those of Mr. F. Emery of Cobridge, Staffordshire, of Messrs. White and Grant of Glasgow, and of Mr. Foudriner. Messrs. White and Grant's cage is simple and inexpensive, no rack-work being required upon the guide-rods, and the suspending power depending upon the simple turning of an eccentric, which is only kept from revolving by the tension of the suspending rope or chain. An eccentric is placed on each side of each guide-rod, and while the tension is sufficient, the narrow parts of the eccentric being toward the rods, there is just room for the guide-rod to pass between them. The breakage of the rope, however, releases the eccentrics, and in their attempt to revolve they grip the guide-rods and prevent the descent of the cage.

Again, a variety of contrivances have been introduced to release the cage from the rope or chain in the event of its being drawn up to the pulley: some of these have been adopted with apparent advantage. Humane care, however, whatever may be the mechanical appliances adopted, is necessary to insure safety.

SAFETY LAMP. Numerous modifications of the Davy safety lamp have been from time to time introduced. A few of the more important must be named:—

1. George Stephenson modified his original plan. His modified lamp consisted of a wire gauze cylinder about 24 inches diameter, and about 6 inches high, with a glass shield inside. The air for combustion was admitted through a series of perforations in the bottom, and a metal chimney, full of small holes, is fixed inside on the top of the glass cylinder.
SAFETY LAMP.

2. Mr. Smith, of Newcastle, improved this by covering all the perforations in the metal with wire gauze.

3. Newman, to meet the objection that strong currents of air, or of gas, could be forced through the gauze, made a lamp with a double wire gauze, commencing from nearly the top of the flame of the lamp, leaving the lower portion with one gauze only; there was no obstruction to the light, and it has not been found possible to light a gas flame by the Newman double gauze lamp, whereas this may be done by suddenly driving the flame through the single gauze of the Davy.

4. Upton and Roberts, fig. 603. Their lamp consists of a wire gauze cylinder $\frac{3}{4}$ inches long and $\frac{3}{4}$ inch in diameter, which is attached to the cylinder in the usual manner. The lower half is protected by a thick glass cylinder, and the remaining portion by one of copper, screwed to the upper ring of the frame. The air for combustion passes through a range of small openings in the upper part of the cistern into a space protected by a double shield of closely compressed wire gauze. A cone of sheet metal stands above this shield and conducts the air directly upon the wick.

5. Martin's lamp was, in many respects, similar to Upton and Roberts's, but so constructed that the flame was extinguished as soon as an explosive mixture was within the glass cylinder.

6. Dumesnil sought to increase the quantity of light, at the same time that he protected the flame against any rapid current. The glass shield surrounding the flame is of carefully annealed glass, and is protected from mechanical injury by curved metal bars; a chimney of sheet metal being above the glass, and all the air being compelled to pass through apertures rendered safe by the use of wire gauze.

7. Dr. Clanny, who had for so many years directed his attention to safety lamps, introduced a new lamp, with an impervious metal shield, having glass and lenses in its sides, only open at the highest part of the gauze cylinder for about $\frac{3}{4}$ inches. Thus there is no admission of air to the lamp, or of the products of combustion from the lamp, except over the top of the shield. This in many respects resembles Musesel's lamp, to be next described.

8. Musselet's lamp is shown in section, fig. 604. The cistern opening for the wick, &c., are precisely the same as we find in the "Davy." A glass shield occupies about two-fifths of the entire height, the lower edge resting in an annular recess on the upper surface of the cistern. A conical tube of metal carries off the products of combustion. Upon the bars which protect the glass rests the gauze cylinder above it. When this lamp is brought into an explosive mixture the flame is first lengthened and extinguished. It unfortunately happens that by turning the lamp on one side the flame is often put out; and in the mines of Liege boys are employed to relight the extinguished lamps. It is, however, stated that not less than 12,000 of these lamps are in daily use in Belgium.

9. Combe's and Loty's are modifications of the preceding.

10. Parish's lamp, one by Dr. Pye, and some others by Mr. Hewitson and Mr. Frim, involve the use of tallow in the place of gas.

11. Eliot's lamp consists of a cylinder fixed upon the upper surface of the cistern and the glass shield, which is pierced with several holes covered with wire gauze, through which the air enters. As in Upton and Roberts' lamp, a cone assists the combustion. A copper chimney is connected with the base, pierced in the upper end with small holes, through which the products of combustion escape. The light is improved by means of a reflector, which slides upon the bars, by which the glass is protected.

12. Dr. Glover, Mr. Cail, and Mr. T. Y. Hall have recently introduced lamps which are so similar to those already named that they need not be described.

13. Mackworth's safety lamp. This safety lamp was contrived by one of the Government Inspectors of coal mines, to meet the objections raised in resisting the general introduction of the Davy lamp into fire-damp mines. The objections were the small light given by the Davy, which is an inconvenience in working high seams of coal, or in picking out the shale and pyrites from the small coal of dirty seams. 2dly, that the Davy was not safe in a rapid current of air and gas, and that glass lamps were not safe in places where the glass might become cracked, besides being heavy to carry; and, 3dly, that the ordinary locks of Davy lamps could be easily picked and opened by the workmen to obtain more light, and light their pipes. The lamp differs from other glass lamps in having a thick outer glass, \( A, \) fig. 605, and a thin inner chimney, \( B. \) The air enters to the flame, as shown by the arrows, through three wire gauzes: 1st, the cylindrical gauze, \( c; \) then through the gauze \( d, \) which supports the brass cover \( r, \) of the glass chimney \( n; \) and, 2dly, through the conical wire gauze \( v, \) which, with its frame, acts as a support to the glass chimney \( u. \) This conical frame throws the air on to the flame \( o, \) so as produce a more perfect combustion and a whiter light. A wire gauze may be placed on the top of the cover \( r, \) but it is unnecessary, as the products of combustion passing through the contracted aperture, prevent any explosion passing up into the cylindrical gauze \( c. \) Of the objects sought to be obtained in this lamp are, the production of from twice to three times the light of the Davy, by a more perfect combustion of oil, throwing the light more
up and down, as shown by the lines m, n. The reflector, J, placed between the glasses, where it is unburnished by smoke, adds to the light. This lamp burns with a steady flame, in currents of air which extinguish other lamps. It is 1½ lb. heavier than a Davy, and 1½ lb. lighter than a Mueseler or a Clancy lamp. The outside glass does not get so hot as in the two latter lamps, which renders the glass liable to be cracked by cold water; and if the outside glass is broken by a blow or otherwise, there is still a perfect safety lamp inside. The mode of locking or riveting the lamp prevents any attempt of the workman to tamper with it. The lead rivet x is clinched by nippers, leaving a die-mark on the lead. This lamp can be locked and unlocked in a shorter time than other locks, which is an object when several hundred lamps have to be given out every morning to workmen.

Some other lamps have been brought forward, the chief object being to prevent the lamp being opened by the miner, one of the most ingenious being the miner's safety lamp, invented by Mr. W. P. Struve, of Swansea.

The sketch, fig. 606, will convey a better notion of it than any written description, and it is only needful to add, that although the diameter of the gauze cylinder at its base is considerably more than that of the Davy, yet owing to the oil-box being placed within the gauze cylinder, instead of below it, and thus occupying a considerable portion of the internal space, the cubical contents of the cylinder does not exceed that of an ordinary Davy. The greater amount of cooling surface near the flame, and the less obstructed admission of air thus obtained, renders it practicable and perfectly safe to use a larger wick than in the Davy, whilst the combustion of the oil is much more perfect, and the smoke very considerably diminished. The light emitted from this lamp has been carefully ascertained to be equal to that

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from three Davys, and owing to the conical form of the cylinder and the shape of the oil-box, it diffuses the light both upwards and downwards, as well as in every other direction, with less shadow than any other lamp that has been offered to the miner. From the more perfect combustion, the consumption of oil in this lamp but slightly exceeds that of the Davy, whilst its simplicity of construction gives great facilities for keeping it in order and for repairs. It barely weighs ½ lb. We learn that this lamp has been extensively introduced into many of the fiery collieries in South Wales.

Illuminating Power of Lamps.

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Average number of lamps required to equal wax-candle standard</th>
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</thead>
<tbody>
<tr>
<td>Davy's lamp, with gauze</td>
<td>8.00</td>
</tr>
<tr>
<td>Stephenson's lamp</td>
<td>15.00</td>
</tr>
<tr>
<td>Upton and Roberts's</td>
<td>24.50</td>
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<tr>
<td>Dr. Clanny's (glass)</td>
<td>2.25</td>
</tr>
<tr>
<td>Musseler's (glass)</td>
<td>3.50</td>
</tr>
<tr>
<td>Parish's lamp, with gauze</td>
<td>2.75</td>
</tr>
<tr>
<td>Davy's lamp, without gauze</td>
<td>2.50</td>
</tr>
<tr>
<td>Common miner's candle, 30 to the lb.</td>
<td>2.00</td>
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</tbody>
</table>

SAL MARINE. Common salt, (chloride of sodium.)

SAL MARTIS. Protosulphate of iron.

SAL MIRABLE. Sulphate of soda.

SALT, FUSIBLE. Phosphate of ammonia.

SALT, GLAUBERS. Sulphate of soda.

SALT, GLAZER'S. Sulphate of potash.

SALT OF LEMERY. Sulphate of potash.

SALT OF TIN. Protosulphate of tin.

SALT, ROCK, SEA, or CULINARY. These terms are used to designate different forms of a substance which is composed, chemically speaking, of single equivalents of sodium and chlorine, or of 39.4 parts of sodium and 60.6 of chlorine in 100 parts by weight: it is known also by the names of chloride of sodium and muriate of soda. (Chlorure de sodium; Hydrochlorate de Soude, Fr.; Chlornatrium, Germ.)

Chloride of sodium generally occurs crystallized in the cube, and occasionally in other forms belonging to the regular system; amongst these varieties, the octahedron, the cube-octahedron, the dodecahedron, have been observed; but there is another which at first sight appears singular, and deserves notice on account of its frequent occurrence. It is called the funnel or hoppershaped crystal; and is a hollow, rectangular pyramid, forming on the surface of a saline solution in the course of its evaporation: it appears to commence with the formation of a small floating cube, to the edges of the upper face of which lines of other little cubes attach themselves by the edges of their lower faces. By a repetition of this proceeding, the sides of a hollow pyramid are formed, the apex of which, the single cubical crystal, is downward: the crystal sinks by degrees as the aggregation goes on above, until a pyramidal boat of considerable size is constructed.

The crystals of chloride of sodium are colorless, but generally contain a little water entangled in their interstices, the expansion of which causes them to decrepitate when heated. This salt is fusible at a red heat, and at a white heat volatilizes. Its crystals are white, frequently perfectly transparent, of a specific gravity of 2.14, and a hardness of 2.5. A remarkable feature in this salt is, that its solubility in water increases but slightly as the temperature of the latter is raised, for, according to the experiments of M. Gay-Lussac, 100 parts of water dissolve

35°81 parts of the salt, at a temperature of 57°0 Fahr.

35°88 " " " 62°2 " "

37°14 " " " 140°0 " "

40°58 " " " 229°5 " "

This must be understood to apply only to the pure substances, for the presence of other salts frequently increases its solubility.

Chloride of sodium, when perfectly colorless and transparent, is also perfectly diathermanous, i.e., it allows the rays of heat to pass through its substance almost without perceptible intercession. It stands first among solid bodies in this respect, all others absorbing a very considerable portion of the heat which passes through them, and some almost the whole:

Of 100 rays of heat Clear rock salt transmits - - 92

" Muddy ditto - - 65

" Plate glass - - 24

" Clear ice - - 0

The source of heat in these experiments was red hot platinum.
SALT.

Chloride of sodium occurs in nature chiefly in two forms, either as rock salt, forming extensive deposits, or disseminated in minute quantity through the mass of the strata which form the earth's crust. Water penetrating the layers of rock salt, and exerting there a solvency action, gives rise to the brine springs which are found in various countries; whilst streams and rivers, dissolving the same substance out of the strata through which they flow, carry it down to the sea, where, from its great solubility, it has gone on gradually increasing, and now constitutes the principal saline ingredient in the waters of the ocean.

Even in mass, i.e., as rock-salt, (Sal gemine, F.; Steinsalz, Germ.) this substance possesses a crystalline structure derived from the cube, which is the primitive form; it generally has a foliated texture, and a distinct cleavage, but it has also sometimes a fibrous structure. Its lustre is vitreous, and its streak white. It is not so brittle as nitre; its hardness = 2-5, which is nearly that of alum; a little harder than gypsum, but softer than calcareous spar. Its specific gravity varies between 2-1 and 2-257. It is white, occasionally colorless, and perfectly transparent, but usually of a yellow or red, and more rarely of a blue or purple tinge. A few analyses will show the general purity of this substance.

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<tbody>
<tr>
<td>Chloride of sodium</td>
<td>100·00</td>
<td>99·50</td>
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<td>Magnesium</td>
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<td>Sulphate of soda</td>
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<tr>
<td>Magnesium</td>
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<tr>
<td>Carbonate of magnesia</td>
<td>100·00</td>
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<td>99·50</td>
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<tr>
<td>Alumina and sesqui-oxide of iron</td>
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<tr>
<td>Clay</td>
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<tr>
<td>Water</td>
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The principal impurities occurring in rock salt are sulphate of lime, oxide of iron and clay, but the chlorides of potassium, calcium, and magnesium, the sulphates of soda and magnesia, and bituminous matters, are sometimes found in it; and occasionally shells, and infusorial remains, exist enclosed in the mass. To the presence of infusoria, indeed is attributed the red or green color with which some varieties are tinted, which, upon analysis, are found to be absolutely pure chloride of sodium, as in the case of the second specimen quoted in the above table. Carburised hydrogen gas in a state of strong compression is met with in some varieties, and those when dissolved in water emit a peculiar crackling sound, caused by the expansion and escape of the confined gas.

The geological position of rock salt is very variable; it is found in all sedimentary formations, from the transition to the tertiary, and is generally interstratified with gypsum, and associated with beds of clay. When the latter is present in large quantity, the term "saliferous clay" is applied to the deposit. The great British deposits of this substance in Cheshire and Worcestershire are found in the new red sandstone. At Northwich, in the Vale of the Weaver, the rock salt consists of two beds, which are not less than 100 feet thick, and are supposed to constitute large insulated masses, about a mile and a half long, and nearly 1,300 yards broad. There are other deposits of rock salt in the same valley, but of inferior importance. The uppermost bed occurs at 75 feet beneath the surface, and is covered with many layers of indurated red, blue, and brown clay, interstratified more or less with gypsum, and interspersed with argillaceous marl. The second bed of rock salt lies 314 feet below the first, being separated from it by layers of indurated clay, with veins of rock salt running between them. The lowest bed of salt was excavated to a depth of 110 feet, seven years ago. Many of the German deposits of rock salt occur in their "bunter sandstein," which is the representative of our new red sandstone, and is so called because its colors vary from red to salmon and chocolate. In the Austrian Alps salt is found in oolitic limestone; at Cordoua, in Spain, in the green sand; and the famous mines of Wieliczka, in Galicia, (excavated at a depth of 860 feet, in a layer 500 miles long, 29 broad, and 1,200 feet deep,) occur in tertiary strata. But in addition to these concealed deposits, this substance presents itself in vast masses upon many parts of the earth's surface: in the high lands of Asia and Africa are often extensive wastes, the soil of which is covered and imregnated with salt, which has never been enclosed by superimposed deposits; near Lake Oceorniah, in the N. W. of Persia, it forms hills and extended plains; it abounds in the neighborhood of the Caspian Sea, and penetrates the entire soil of the steppes of the south of Russia.

The beds of rock salt are sometimes so thick, as at Wieliczka and Northwich, that they have not yet been bored through, although mined for many centuries; but in ordinary cases the thickness of the layers varies from an inch to two or ten or fifteen yards. When the strata are thin, they are usually numerous, and throughout a certain extant parallel, but
when explored at several points such enlargements and diminutions are observed as to destroy this appearance of parallelism.

It has been remarked that the plants which generally grow on the sea-shore, such as the *Triglochinum maritimum*, the *Salicornia*, the *Salsola kali*, the *Aster trifidum*, or farewell to summer, the *Glaux maritima*, &c., occur also in the neighborhood of salt mines and salt springs, even of those which are most deeply buried beneath the surface. It is also generally found that the interior of salt mines is extremely dry, so that the dust produced in the workings becomes an annoyance to the miners, though in other respects the excavations are not insalubrious.

Much discussion has been raised concerning the origin of these rock-salt deposits; some asserting that they were the result of igneous agency, and others that they have been in every case deposited from solution in water. The great argument in favor of the former view appears to rest upon the fact that chloride of sodium and hydrochloric acid gas are among the substances erupted by volcanoes; whilst on the other hand it is urged that the specimens of erupted chloride of sodium which have been analyzed always differ much from rock salt, since they contain a large amount of chloride of potassium; and in addition to this, the frequent occurrence of bodies such as bitumen and organic remains, and of cavities containing liquids, and in some cases gases, in almost all varieties of rock salt, are held to furnish indisputable proof of the deposition of this substance from its aqueous solution. The occurrence of salt in parts of the world the coldest for the production of these thalassic plants, and so also does the general character of these deposits; they are usually lenticular, or irregularly shaped beds, having a great horizontal extension, and but rarely occur in the form of dikes, or masses filling vertical fissures, which is the usual form assumed by a molten mass projected upwards from the interior of the earth. The method of its formation was, according to those who hold the aqueous theory, somewhat as follows:—A sea, such as the Mediterranean, is, by an elevation of the land at Gibraltar, cut off from communication with the ocean—the rate of evaporation from its surface is greater than the supply of water by rain and rivers, consequently the amount of salt which it holds dissolved, increases; now chloride of sodium is the principal saline constituent of sea water, and Bischof's experiments have shown that when a solution of this salt is allowed to be at rest, the particles of salt sink, so that the lower layers soon become more saturated than the upper; concentration is then supposed to go on until at the undisturbed bottom of this inland sea a saturated solution of chloride of sodium exists, from which masses of rock salt are slowly deposited. Its great purity is accounted for by the fact, that the other salts existing in sea water are either far less or far more soluble than chloride of sodium; thus the carbonate and sulphate of lime would be almost wholly precipitated before the solution became sufficiently concentrated to deposit rock salt, whilst at that degree of concentration the sulphate and chloride of magnesium would still remain for the most part in solution.

The principal European mines of rock salt are those of Wieliczka, in Galicia, excavated at a depth of 680 feet below the soil; at Hall, in the Tyrol, and along the mountain range through Aussee, in Styria, Ebensee, Ischl, and Halbstadt, in Upper Austria; Hallen in Salzburg, 3,000 feet above the sea level, and Reichenthal in Bavaria; in Hungary, at Marmoreas; in Transylvania and Wallachia; at Vie and Dicouze in France; at Bex, in Switzerland; in the Valley of Cardona, and elsewhere, in Spain; and in the region around Northwich, in Cheshire, in our own country. Some of these deposits, as at Wieliczka and Northwich, are almost pure chloride of sodium; others, again, as many of the Austrian beds, are only saliferous clay; whilst others, as at Arthorne in Savoy, elevated 7,200 feet above the level of the sea, and in the region of perpetual snow, are masses of saccharoid gypsum and anhydrite, which are imbued with chloride of sodium, and which become quite light and porous when the salt has been removed by water.

The natural transition from the consideration of these strata of rock salt is to those brine springs which generally accompany them, and which have frequently first called attention to the deposits below. It has been noticed that salt springs issue, in general, from the upper portion of the saliferous strata; cases, however, occur in which the brines are not accompanied by rock salt, and in which, therefore, their whole saline contents must be derived from the ordinary constituents of the strata. Thus, in England, besides the strong brines of the new red sandstone, we have salt springs issuing from the carboniferous rocks. The purest and most saturated brines are, however, found to be those which can be traced to rock salt beds, and in the foremost rank of these stand the English springs of the Northwich, Middlewich, and Sandbach districts in Cheshire; of Droitwich and Stowe, in Worcestershire; and of Weston and Shirleywich, in Staffordshire; and the continental brines of Wirtemberg and Prussian Saxony. See first table, p. 965, for the composition of these saturated brines. Compared with these may be some weaker and less pure brines issuing from the same geological formations. The brines in the United States come for the most part from Silurian sandstones, but those in the Alleghany Mountains spring from the coal; and the weak salt springs of Nauheim and Homburg, which can only be called brines because chloride of sodium is their largest constituent, rise from transition strata. See second table, p. 965.
SALT.

I. Solid contents in 100 parts of brine.

<table>
<thead>
<tr>
<th>Chloride of sodium</th>
<th>Chloride of magnesium</th>
<th>Phosphate of lime</th>
<th>Carbonate of soda</th>
<th>Silicate of soda</th>
<th>Solid contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGLAND.</td>
<td>WURTENBURG.</td>
<td>PRUSSIAN SAXONY.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chester.</td>
<td>Friedrichshall.</td>
<td>Hall.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marston.</td>
<td>52.322</td>
<td>25.333</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheelock.</td>
<td>52.333</td>
<td>25.492</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Droitwich.</td>
<td>25.631</td>
<td>119</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stoke.</td>
<td>25.492</td>
<td>119</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

II. Solid contents in 100 parts of brine.

<table>
<thead>
<tr>
<th>Chloride of sodium</th>
<th>Chloride of magnesium</th>
<th>Phosphate of lime</th>
<th>Carbonate of soda</th>
<th>Silicate of soda</th>
<th>Solid contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMERICA.</td>
<td>HESS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mountains.</td>
<td>Kaisersquelle.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.239</td>
<td>32.000</td>
<td>27.302</td>
<td>16000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.038</td>
<td>0.038</td>
<td>0.027</td>
<td>0.027</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.038</td>
<td>0.038</td>
<td>0.027</td>
<td>0.027</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.026</td>
<td>0.039</td>
<td>0.018</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>Bromide of potassium</td>
<td>magnesium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.059</td>
<td>0.059</td>
<td>0.007</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.014</td>
<td>0.002</td>
<td>0.015</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.002</td>
<td>0.002</td>
<td>0.006</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.030</td>
<td>0.030</td>
<td>0.029</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td>Sulphate of lime</td>
<td>0.030</td>
<td>0.030</td>
<td>0.029</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td>Carbonate of lime</td>
<td>0.014</td>
<td>0.002</td>
<td>0.015</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>Silicate of soda</td>
<td>0.006</td>
<td>0.006</td>
<td>0.006</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td>Solid contents</td>
<td>13.239</td>
<td>4.009</td>
<td>3.139</td>
<td>18496</td>
<td></td>
</tr>
</tbody>
</table>

These weak salt springs are supposed to have no connection with beds of rock salt, but to obtain their chloride of sodium, in common with the other salts which they contain, from the strata which they permeate. The singular brines of the Alleghany Mountains must obviously pass through strata containing little if any soluble sulphate, otherwise their chloride of barium would be separated as insoluble sulphate of baraya; and all indeed may be regarded as coming more under the head of ordinary mineral waters, which happen to contain rather a large quantity of chloride of sodium.

The next source of chloride of sodium which demands notice is found in the inland seas, salt lakes, pools, and marshes, which have their several localities obviously independent of peculiar geological formations. They appear to owe their origin to two causes, being due, firstly, to the formation of lakes upon, and the passage of rivers through, some of the surface deposits of salt already alluded to; and, secondly, by the cutting off of a portion of the ocean by the elevation of the land, and the consequent formation of an inland lake. To the former cause are probably due the existence of the Lake Oroomiah in the N. W. of Persia, the numerous brine pools of Southern Russia, and the Great Salt Lake of N. America. The Lake Oroomiah is 82 miles long by 24 wide, and elevated 4,000 feet above the level of the sea; it is surrounded, especially on the east and north, by some of the most remarkable surface deposits of rock salt in the world, and through these salt streams are continually flowing into the lake. The Russian brine pools are situated in the salt-impregnated steppe between the rivers Ural and Wolga, and doubtless derive their saline constituents from thence. The Great Salt Lake is a saturated solution of almost pure chloride of sodium, but whence the salt is derived appears at present to be but a matter of conjecture. To the sec-

The cause the origin of the Dead Sea is frequently attributed; its surface is about 1,300 feet
below that of the Mediterranean, and it is thought to have lost a column of water of that height by evaporation. The Crimean lakes also have probably originated thus.

Bishof has shown that in proportion as chloride of magnesium increases in a solution, it renders chloride of sodium and sulphate of lime more and more insoluble; he is therefore of opinion that at the bottom of the Dead Sea, and similar lakes, an impure rock-salt deposit, interstratified also with mud, is forming, similar to the saline clays or chalybeate marls which are frequently met with on the continent.

The three following analyses exhibit the peculiarities of two classes of salt lakes: Lake Oroomiah, formed by the solution of pure rock salt, contains but little magnesia salt, whilst the Crimean Lake and the Dead Sea, produced probably by the evaporation of sea water, show how the very soluble salts of magnesia increase as the water concentrates.

### Solid contents in 100 parts of water.

<table>
<thead>
<tr>
<th></th>
<th>Dead Sea</th>
<th>Lake Oroomiah</th>
<th>Siwach, or Putrid Sca, Crimea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride of sodium</td>
<td>5878</td>
<td>19-92</td>
<td>14-20</td>
</tr>
<tr>
<td>&quot; potassium</td>
<td>1298</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&quot; calcium</td>
<td>2094</td>
<td>-</td>
<td>04</td>
</tr>
<tr>
<td>&quot; magnesium</td>
<td>8145</td>
<td>52</td>
<td>1-93</td>
</tr>
<tr>
<td>&quot; aluminum</td>
<td>018</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bromide of magnesium</td>
<td>021</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulphide of calcium</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulphate of lime</td>
<td>068</td>
<td>1-8</td>
<td>-</td>
</tr>
<tr>
<td>&quot; magnesium</td>
<td>-</td>
<td>-</td>
<td>21</td>
</tr>
<tr>
<td>Organic matter</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Solid contents</td>
<td>21-770</td>
<td>20-05</td>
<td>17-38</td>
</tr>
</tbody>
</table>

Finally, to compare with the above results, the composition of the sea may be given: numerous analyses have been made of the water taken at widely distant points, and at different depths, and the difference in composition has been small. The water of some partially enclosed seas, as the Baltic and Black Seas, into which numerous rivers pour, is below the average concentration, and that of others again, as the Mediterranean, is above that point. The deep sea water is also more concentrated than that at the surface, as Von Bibra has shown that the Pacific Ocean, in 25° 11' S. and 93° 24' W. contains 3-47 of saline matter in 100 parts, at a depth of 11 feet, whilst at a depth of 420 feet it contains 3-52. Bishof’s experiments, before alluded to, would lead to this supposition. The following analyses are by Von Bibra, except the last, which is by Laurent:

### Solid contents in 100 parts of sea water.

<table>
<thead>
<tr>
<th></th>
<th>English Channel</th>
<th>Pacific Ocean</th>
<th>Atlantic Ocean</th>
<th>Mediterranean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride of sodium</td>
<td>5295</td>
<td>2557</td>
<td>2759</td>
<td>2719</td>
</tr>
<tr>
<td>&quot; potassium</td>
<td>067</td>
<td>116</td>
<td>154</td>
<td>001</td>
</tr>
<tr>
<td>&quot; magnesium</td>
<td>259</td>
<td>359</td>
<td>333</td>
<td>613</td>
</tr>
<tr>
<td>Bromide of sodium</td>
<td>11</td>
<td>029</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulphate of lime</td>
<td>111</td>
<td>312</td>
<td>155</td>
<td>015</td>
</tr>
<tr>
<td>&quot; magnesium</td>
<td>225</td>
<td>204</td>
<td>184</td>
<td>701</td>
</tr>
<tr>
<td>Carbonate of lime</td>
<td>001</td>
<td>-</td>
<td>001</td>
<td>019</td>
</tr>
<tr>
<td>Solid contents</td>
<td>3278</td>
<td>3467</td>
<td>3507</td>
<td>4069</td>
</tr>
</tbody>
</table>

The average specific gravity of sea water is from 1-029, to 1-030.

Culinary salt is prepared from each of the four sources above mentioned; but it rarely happens that rock salt is sufficiently pure for immediate use, and when employed, as in some places on the continent, and formerly in Cheshire, it is dissolved in water, the insoluble impurities allowed to subside, and the solution treated as a concentrated brine. From its other sources, salt is obtained by evaporation, and this is effected in two ways: 1. Entirely by the application of artificial heat; 2. By natural evaporation preceding the application of artificial heat.

The first method is employed invariably in this country, and also on the continent when the brines contain more than 16 or 20 per cent. of chloride of sodium, the cost of fuel at different places of course regulating the application of this method. The manufacture of salt at Droitwich in Worcestershire, is said to have existed in the time of the Romans, and
SANITARY ECONOMY.

In Cheshire, the "Wiches" were very productive in the reign of Edward the Confessor; some time elapsed before the method of evaporation was devised, and the original mode of obtaining the salt was by pouring the brine upon the burning branches of oak and hazel, from the ashes of which the deposited salt was afterwards collected. The process of evaporation was first conducted in small leaden vessels, which were afterwards exchanged for iron ones, having a surface of about a square yard, and a depth of six inches; the size of these pans increased but slowly, for only a century since the largest pans at Northwich were but 20 feet long by 10 broad. The pans now in use in Cheshire, Worcestershire, and Staffordshire have a length of 60 or 70 feet, with a width of from 20 to 25, and a depth of about 18 inches; they are made of stout iron plates riveted together, are supported on brickwork, and have from one to three furnaces placed at one end, the flues of which are in immediate contact with the bottom of the pan. In the works of Mespess, Kay of Winsford, the brine is heated to its boiling point in a small iron reservoir, and from thence caused to circulate through a series of brick-lined channels until it is again, by a simple arrangement, pumped into the first iron vessel, and heated afresh. The brine is generally raised by steam power, and its supply appears inexhaustible. The shafts are lined with wooden or iron casings to prevent the admixture of fresh-water springs with the brine; the depth of the borings is in Cheshire usually from 210 to 250 feet, but at Stoke, in Worcestershire, a shaft of 225 feet was constructed, but no satisfactory supply of brine obtained until a further boring of 348 feet was made. At Droitwich the borings are only to a depth of 175 feet, and so abundant is the supply of brine, that if the pumps cease working, it speedily rises to within nine feet of the surface, and if left uncovered soon overflows. The freedom of the brine from borings by fresh-water springs is from time to time tested by the hydrometer. From the pumps the brine is directly conveyed by means of pipes to reservoirs, from which, as the evaporation proceeds, it is admitted into the pans. As the water is vaporized, the salt is deposited and falls to the bottom of the pan; it is then drawn to the sides by the workmen, until a heap is accumulated, and from this portions are ladled out into rectangular wooden boxes with perforated bottoms, allowed to drain and solidify, removed from the boxes, and placed in the drying room; the salt of coarser grain is simply drained roughly in baskets and dried. The grain of the salt, i.e., its occurrence in larger or smaller crystals, is entirely the effect of temperature; the fine grained or table salt is produced by rapid heating, and is formed at that end of the pan next the fire-place; the coarse or bay-salt is formed by the slow evaporation which goes on at the other end; whilst an intermediate variety, common salt, is produced in the middle. A pan may sometimes be slowly evaporated for the express purpose of obtaining bay-salt.

In the preparation of salt various substances have been added to the brine with a view of improving the quality of the product; these have been chiefly bodies containing albuminous matters, which, coagulating upon the application of heat, entangle all solid impurities and carry them to the surface; blood, white of egg, glue, and calves' feet have thus been extensively used. There is also another class of substances employed for a different purpose. When a concentrated solution of any saline matter is evaporated, much annoyance is caused by a layer of the solid salt forming on the surface of the liquid and impeding evaporation; this is called a "pellicle," to obviate this, and to avoid the loss of labor entailed by constant stirring, oils, butter, or resin have been added to the brine. The effect of the latter is said to be perfectly magical, the introduction of a very few grains being amply sufficient to clear the largest pan, and to prevent any recurrence of the "setting over."

SANITARY ECONOMY. This term is used to express and to include every thing which is done or can be done towards the preservation of health, but in its more restricted and usual sense it is the method of preserving the health of communities. It therefore interests the largest communities, such as nations, and the smallest, such as families, whilst of necessity the interest of the individual is not forgotten; and there is a point at which it merges into medicine or medical economy. It is sometimes called sanitary science, but it is not well to be very lavish of the world science, which, although originally only knowledge, is now better confined to cases in which nature herself has pointed out a definite system of laws. Now all those facts brought into prominence by sanitary economy are more or less connected with some science the laws of which are investigated in other relations; but so wonderfully does nature act, that isolated facts from all the sciences frequently come out and form a series so connected, that for a time the judgment is in favor of believing that they may be so arranged as to form a true science; and in some cases this is an open question. Many sciences, perhaps every science, assist in the art of true sanitary economy. Its necessity has arisen from that class of misfortunes to which man has been subject affecting his health; or, as some would say, from certain defects of nature which man is required to supplement. Many of these defects are told in a long series of the greatest miseries; some in a long series of more limited but constant sorrows; and others have been sufficiently small to be considered rather as annoyances. In "Bascombe's History of Epidemic PESTIENCES," we may read of many hundreds that attacked man in every known country, and, we may almost add, in every age. In the East we have frequently mention of plagues.
SANITARY ECONOMY.

Plagues have frequently followed the track of great, and especially of defeated armies, as well as taken refuge in beleaguered cities.

Hecker's "Epidemics of the Middle Ages" shows few years in which some part of the world has not been suffering under an epidemic. In our own times cholera has long been known to be seldom quite extinct. As an instance of the mode in which these epidemics travel, let us follow the track of cholera. It first appeared at Jessore, on the Delta of the Ganges, reached Judah and Java, and the Burmese Empire in 1818; Bombay, in August of the same year, Baraean and Malacca; in 1819, Penang in Sumatra, Siam, Ceylon, Mauritius, and Bourbon; in 1820, in Tonquin, Cambodia, Cochinchina, South China, Philippines; in 1821, Java, Bantam, Madura, Borneo, &c., Muscat in Arabia, and Persian shores; in 1822-23-24, Tonquin, Pekin, Central and North China, Moluccas, Amboyna, Macassar, Assam; in 1822-23, Persia, Mesopotamia, Judea; in 1826, Astrachan, part of Russia; in 1827, Chinese Tartary—in all these countries committing ravages hitherto unheard of. In 1830 it went back to Russia, to Poland, Moldavia, and Austria. In 1851 it appeared in Riga and Dantzig, Petersburg, Berlin, Vienna, Sunderland, Leith, and Calais; in 1852, in London; 1834, Spain, the Mediterranean, and North America. In Arabia, one-third in the chief towns died; in Persia, one-sixth; in Mesopotamia, one-fourth; in a province of Caucasus, 10,000 died out of 16,000; in a province of Russia, 31,000 out of 54,000. Plagues are, therefore, still capable of exercising a fatal influence equal to that of the most ancient tyranny. In European towns generally the greatest number of cases are perhaps simply due to the destitute of cleanliness in the districts least provided with means of cleanliness. It was found among the poor and ill-fed, among the dark races, and the grades of lowest constitutional power. (Copland's Dictionary:—Pestilence.) It is also to be remarked, that in all the places where cholera was most violent, civilization had not attained its European maximum. Cholera is an attack of the chemical forces on the vital forces; vital force even in the form of moral confidence repels it to a great extent, as it does other infectious diseases; but, for the same reason, fatigued and depressed mind hasten the action. The ordinary chemical forces act in the viscera instead of the chemical-vital. The lungs are gorged with blood, unable to send it away oxidized; the gall increases because carbon is not burnt, and urea is not secreted as there is no normal decomposition of the food. Vital force therefore fails, and a kind of putrefaction or fermenting action begins. This is only one instance of the many evils that have followed man. This is not the place to speak of black death, sweating sickness, and the other diseases, down to milder influenzas, which are continually infesting some of our race.

Diseases of this kind are believed to be caused by decomposing matter; they seem to rise from fecal cities or fecal land. Deltas have been chiefly blamed; that of the Ganges for cholera, that of the Nile for plague, that of the Mississippi for yellow fever. Although from this view diseases would be considered as under the power of mankind to suppress, their cause seems too widely diffused to place them under the direct control of limited communities, much less of individuals.

About 1350 the whole world was thrown into violent commotion. The change may be said to have begun in 1348, when floods, earthquakes, and sinking mountains are spoken of as occurring in China. Plague and parching drought covered much of the East; Cyprus was nearly destroyed. In that island the earth opened and sent out a fetid vapor which killed many. A mist, thick and putrid, came to Italy from the East. Earthquakes occurred all along the Mediterranean. Noxious vapors and chasms seem to have extended hundreds of miles. (Hecker.) Diseases from these causes are of course out of our control. Another natural source of disease is the existence of marshy producing malaria. Malaria may also be produced from woody land and moist land, especially if there be many impurities. Deltas, or low lands, at the mouths of rivers, land flooded either by salt or by fresh water, especially if alternately by one and the other, not forgetting the great alluvial deposits, which are kept moist in hot climates. Numerous as are the cases of malaria where it is difficult to see the cause, the connection of the marshes with some febrile diseases is beyond any question. The fever from this source seem in their worst states to pass into yellow fever. This class of fevers is not epidemic, and does not travel far from its source. There are of course many cases of its being carried by the winds to a great distance, and the distance seems to depend on the amount of marshy land, or, in other words, on the extent of the poison produced. If little exist, it is dispersed before the wind travels far.

Conditions of the earth may cause vegetation to perish. In 1690, a striking example of this occurred at Modena, although other examples might be taken much nearer, if there were not such multitudes of opinions upon them. Four or five years of unusual dryness had occurred; fruit was abundant, however, and health satisfactory. A wet winter came, cloudy and calm, without cold. This state continued through summer, with much rain. The numerous and noisy grasshoppers of Italy almost ceased, and frogs, that belong to a country of marshes, took their place. The corn had ceased to grow, and its place was supplied by fishes, so abundant was the water on the land; whilst also organic matter was driven into the streams in unusual quantities. Vegetation was attacked with violet—a rusty withered appearance—which increased in spite of all precaution; begin-
ning with the mulberry, it attacked the corn, and then the legumes, and especially the beans. This extended over the higher spots as well as the lower. It was melancholy to look on the fields, which, instead of being green and healthy, were everywhere black and sooty. "The very animals returned the food which they had eaten. . . . The sheep and the silkworms perished. . . . The bees made their honey with timidity. . . . The waters became corrupt, and fevers attacked the inhabitants, chiefly the country people, such as lived on the wet lands. This state produced intermittent fevers."—Bern. Romazzini.

Again, there are causes purely artificial arising from the state of our towns in manufacturing districts.

It has been proved that diseases may be produced artificially of a kind closely resembling the great world epidemics. When persons live closely crowded together health gradually begins to fail, and loathsome diseases rapidly grow. These diseases very immeasurably, and the variation seems to be as great as the modes of decomposition of animal matter. After a time these diseases attain virulence sufficient to be infectious or contagious through the atmosphere.

These various conditions are not perfectly understood, but even the statement of our ascertained knowledge has been most widely misunderstood by the public, and sometimes even by professional men, many of whom, if they have conceived the matter clearly, have not expressed it well.

There are at least three principal methods by which the air is rendered impure. 1. by noxious gases, dust, and ashes, produced by geological, atmospheric, or artificial causes, sulphurous gas, carbonic acid, sulphuretted hydrogen, and perhaps many others. 2. Epidemic or travelling causes to all appearance reproducing themselves as they advance, as in plague and cholera. Similar diseases produced by artificial or neglected accumulations of filth. 3. Malaria, or diseases caused by the disturbed or badly-regulated relation between the soil and the atmospheric conditions, whether from natural or artificial causes. It would be difficult to include all the various evils arising from too much heat, cold, &c., &c.; knowing these things, we are able to a considerable extent to guide ourselves. When the disease or nuisance is caused by processes of manufacture the law sanctions interference. The judicious management of this branch of the subject is of the greatest importance to the community.

There are also causes of disease relating more to the condition of the atmosphere; for example, from the prolongation of a current of air or wind from one particular district, without due mixture; and from conditions of moisture, and of electricity.

Sanitary economy devises a method of avoiding the diseases produced of. As to the first, those produced by geological phenomena, our chief protection lies in the choice of place: this remark may also apply to those diseases produced by atmospheric stagnation and electrical condition. All we can do is to choose places which are known to be free from disturbances or irregularities; when such occur, we are then able only to remove or to suffer. Such diseases are but little understood. When the disease is epidemic, some trace its origin to causes which may be termed cosmic. One may be an excess of the decomposing agent, or by conditions of the atmosphere unfavorable to the continuation or tenacity of delicate chemical compounds. Take, as illustration, milk during a thunderstorm: this action is probably caused by a very rapid oxidation, which oxidation begins the phenomena of putrefaction. To bring such an analogy to explain the condition generally of organic matter, is legitimate, and we may either suppose the action to begin in living animals themselves, or on substances external to them. The belief may be said to be established by a long host of great observers, that putrefying matter produces diseases under certain not very well known conditions, and that it reacts unfavorably on the health in every condition, and as a cause of instant death in concentrated forms. In Cairo, where houses are crowded with the living, and where the dead are buried with slight covering, underneath the living, there seems to be a periodic clearing out of the population by plague, reducing the number until there be enough of air to allow of healthy life. In our own prisons at one time the same thing occurred, and in many of the prisons of the world imprisonment is death; such as in Turkey, China, and places not civilized by modern sanitary knowledge. Prisons in Europe, also might readily be mentioned as most unwholesome; and prisons and workhouses in England itself, where the greatest care must be taken to prevent want of cleanliness, as it produces an immediate result in disease. This is merely on a small scale what takes place on a great scale in nature. It is similar to what we every day see, that man lays hold of some of the facts of nature, and under his hand they act by the same laws as they do in their cosmic manifestations. So in his diseases, man produces them by causing circumstances so to concur that the laws of nature act under his hand as they do when he has not interfered. Sanitary inquirers have ultimately been compelled to attribute many of the greatest effects on health to decomposition of organic matter. Almost all ages have referred to putrefaction or fermentation as an evil. The words have been used synonymously. For various opinions on this subject see Disinfectant. M. Place, in 1721, says that in putrefaction a body works another to conformity with itself. This is believed to be
the case in many diseases. One erroneous opinion is very common. Gases which might be prepared in the chemist's laboratory have been blamed as the causes of infectious diseases. Sulphuretted hydrogen and carbonic acid are spoken of as if they were infectious, and productive of fevers. Permanent chemical compounds, gaseous or otherwise, are not capable of acting as infections. The idea of infection given is that of a body in a state of activity. But any gas, the atmospheric mixture excepted, is capable sooner or later of causing death. A true gas diffuses itself in the air, and is rapidly removed from any spot; to render a place long unwholesome the gas must be continuously generated at the spot. The movements of plagues are not similar to anything we know of gases; on the contrary, we know that gases could not move in the manner that cholera and plague do. Sulphuretted hydrogen is not miscible, it is poisonous; it may destroy the constitution and produce diseases which may be deadly enough, but the sources of it are resorted to by invalids; this would never be the case were it a misnm.

It has occasionally an internal beneficial action, and although in using it a little be taken into the lungs, this momentary breathing is not found prejudicial; but an amount of cholera infection, such as we could perceive by the nose as readily as sulphuretted hydrogen, would not doubt be a most deadly dose; we probably know of no such amount. The same may be said of carbonic acid and other gases. Some persons are capable of smelling the misnm of certain places—no doubt very fine senses could detect them wherever they existed; but generally bad air may injure very important organs without any evil being perceived by the senses until the evil has become very great. The chemical action is not one that the senses fully observe. Fermentation and putrefaction exhaust their powers after a short time, and cease; so do infections, but not so pure gases, which act only by combining. The fermenting substances lose their power not by combination so much as a change of condition, a transformation of their particles. All these actions, similar to fermentation, are connected with moist bodies: dried bodies cannot ferment, putrefy, or infect. (See PUTFRECTION, vol. ii.) Infection, like fermentation, is most violent at an early stage, gradually spending its strength, and frequently changing a portion of the substance into analogous forms. It has been argued that putrefaction cannot produce disease; but there are no facts in nature better established than the production of disease by the presence of dead animals or vegetables, especially the first. The production of fever by crowding hospitals, barracks, and ships, is as easy as the formation of many other artificial organic actions, although no exact form of fever can be produced at will; cases depending no doubt on time, place, climate, and constitution. The knowledge of these facts concerning zymotic diseases leads to this conclusion: in order to avoid the evil effects of decaying matter, it is necessary to have all our surroundings as clean as possible. Sanitary economy resolves itself at last chiefly into cleanliness. Individuals may learn personal cleanliness, but to render a town or a county clean many difficult arrangements are needed. Impurities arise from the conditions of animal life. Life is generated by the activities of certain substances which compose animals. When the activity is over the substances are dead and unpleasant, and they pass into their former condition through a number of stages. In some of these stages the substances are gaseous, some liquid, some solid; we may add, some in the state of vapor. Some of these substances are exhalations from the surface of the whole body, but from the lungs principally. The lungs give out air with about 4, 6, and even 8 per cent. of carbonic acid in it, and the amount respired is about 350 cubic feet in 24 hours, and about 31 cubic inches per respiration, and 15 respirations per minute. The amount of air proposed as the supply for an individual varies greatly. Dr. Reid gave 30 cubic feet per minute = 1,800 feet per hour, and even 3,600. Liebig supposes at least 2,000. Dr. Reid gave more than was considered agreeable. Brennan supposes about 600, and calculates the following for every room per minute per individual, the air being at 64°, and dew point at 50°:

<table>
<thead>
<tr>
<th>For supply to the lungs</th>
<th>-</th>
<th>-</th>
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<th>0·83 feet</th>
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<tbody>
<tr>
<td>To carry off insensible perspiration</td>
<td>-</td>
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<td>-</td>
<td>10·2</td>
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<tr>
<td>For each common-sized candle</td>
<td>-</td>
<td>-</td>
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<td>0·25</td>
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If heated air is used for warming—

| For each square foot of glass in the window | - | - | - | 1·0 " |
| Each window to make up for leakage | - | - | - | 8·5 " |
| Each door for the same | - | - | - | 5·2 " |
| Each 200 square feet of wall and ceiling | - | - | - | 1 " |

Allowing this to be excessive, the advantage of pure air is still to be urged, and it is desired most by the healthiest specimens of men.

In speaking of the impure gases of the air, carbonic acid is generally referred to.

This carbonic acid has been considered to be the great cause of disease in crowded localities, but the conclusion is contrary to our knowledge of the effects of carbonic acid when pure. There can be little doubt that there is a considerable amount of organic matter in the air of crowded places, and to that organic matter must be attributed most of the
evil. It may be true that 1 per cent. of carbonic acid may be observed by the senses, but this is generally tried with carbonic acid given out from the lungs. In the case of a prison in Germany, 2 per cent. of carbonic acid was found in the air. Skin diseases appeared rapidly, and deaths were excessive. But we do not know the action of the pure gas; there must have been a large amount of corrupt matter in air which contained 2 per cent. of carbonic acid escaped from persons. It shows also great general filth. Amounts of organic matter, which are wonderfully less than even a hundredth of a per cent., are known to make the air unhealthy. In Manchester it seems to be the sulphurous acid which is chiefly felt, and that when it is less than one in a million, although it rises up in some places close to chimneys to 1, and even 4, in 100,000.

It is not intended here to give statistics of disease, but it will be right to refer to the enormous amount of disease amongst miners in Cornwall. The depths being great, above 1,800 feet in some, and the temperature rising to about 100°, the difficulty of working is extremely great. Candles are burnt, and the air has become so deteriorated that it contained less than 18 per cent. of oxygen. The amount of carbonic acid had not risen above 0.08 per cent., which is not very high. Mr. R. Q. Couch, Sir J. Forbes, and Mr. Mackworth, have successively reported on this subject and given some interesting details. Mr. Robertson, of Manchester, remarks on the great cleanliness of the women; but they do not enter the mines, and their lives are longer. Consumption destroys the men rapidly in many of the deep mines.

Exhalations from the skin are abundant, both acid and oleaginous. Dr. Vogel found organic matter in the air of his class-rooms after a lecture. Dr. Angus Smith has shown that the exhalations may be traced on the walls of crowded rooms, which become coated with organic matter; and he adds that the furniture becomes coated with a similar substance, which must be continually removed. Thus furniture and walls which are never touched in time become impure, and give out noxious exhalations when such substances begin to decompose. Again, these substances are caught in our clothes and are retained there in a decided manner, on account of a peculiar faculty of retention in the fibre. This necessitates constant washing. Long custom has shown, that when retained by the cloth, a certain amount of it becomes innocent; that is, different fibres have the power of retaining matter so firmly that it is imperceptible and incapable of acting on the air. Wool has this faculty to a great extent; linen and cotton to a less extent. For this reason wool can be worn longer next the skin, remaining in reality clean. Clothes that are to be kept in good condition, if made of wool, as men's coats, cannot be washed; for this reason the custom has gradually been formed of wearing under clothing, which absorbs condensible substances especially, and is then washed, keeping the exterior clothing for a long time clean. As porous substances have an oxidizing power, it is probable, that if not too much organic matter is supplied, the exterior clothing, well aired, may be kept absolutely clean, not merely by our ordinary practice of brushing and dusting, but also by oxidation, in the same way as Dr. Stenhouse has shown oxidation to take place in pores of charcoal. The instant removal of the breath and other exhalations is of great importance. This property comes under the head of warming and ventilating. Walter Brennan, C.B., in his "History of Warming and Ventilating," gives a remarkable amount of information. There have been many mistakes as to the effect of overcrowding; its evils have actually been denied. The facts are very decided. Isolated houses may be crowded so much as to produce diseases, or they may be so badly ventilated without crowding as to have the same result. In this way persons in the country may have all the disadvantages of a crowded town. Again, a town-house well ventilated may have many of the advantages of the country, because, although the air is not of the purest, it may never be allowed to sink below the average purity of the external air. Indeed, freedom from disease is obtained in towns better in all cases than where there is a malarious atmosphere outside the town; this, of course, is well known; and at the same time diseases from putrefaction, caused by want of space and cleanliness, are cured by leaving a town. Persons slightly exposed to the odor of water-closets in towns are frequently subjected to disease, the unoxidized air poisoning them, whilst persons working in the open air escape, although laboring amongst the excreta themselves. Again, persons living in the house are exposed to the excreta a day or two old, whilst in the case of nightmen, it has frequently passed its worst stage when they approach it. The stage giving off sulphurated hydrogen is by no means the worst, perhaps one of the most innocent of the unpleasant stages, unless this gas be very strong, when it is fatal. But even in the minutest quantity this gas is hurtful to persons continuously exposed.

The mode of removing excreta is an important point. Most inquirers have decided against leaving them in a town, and against allowing them near a house. These conclusions are especially valuable for town houses. We have in some towns whole streets of middens behind the houses, and the air behind is always inferior to the front air. The process of cutting refuse is also a great evil in a town. No plan removes filth so rapidly as that which

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* "Miner's consumption," as the disease which destroys the miner is named, prevails also in the lead mines of the northern counties, which are usually shallow.—(Ed.)
SANITARY ECONOMY.

water. Many people object to it, because we have not yet learnt to make good sewers. Sewers should be tight. The Board of Health introduced small and rapid streams in the sewers, objection to the canal-like sewers, which are as bad as cesspools, on account of the enormous amount of deposit in them, and are reservoirs of foul air from the amount of putrefaction going on within them. Many persons, not seeing this evil, have desired again to return to the no-plan of middens, not seeing what a deplorable result has been attained in Paris, where although using air-tight vessels to remove the refuse, they render most of the houses redolent of night-soil. The towns treated on the rapid removal system are models of cleanliness, and we do not doubt the speedy increase of the plan, especially as carried out by Robert Rawlinson, C.E. It must be confessed, however, that the great objection to the plan is one which is not to be dreaded. There is too much water used; if the water flows into the streams they are spoiled, and it is scarcely possible to put it on land. This difficulty must be met, or the plan so admirable for towns will be found destructive to countries. There is one way of meeting it, that is, by making the liquid denser, and so having it so strong as to be a valuable manure. By a double system of drainage this might be effected, the rain water going in a separate sewer. F. O. Glassford proposes a water-closet which shall hold the excreta till they are mixed up to a thickish liquid with water; he then removes it by pipes to certain reservoirs, and makes solid manure from it by sulphuric acid and evaporation, a plan which he has found to answer. Dr. Joule proposes larger iron tanks for each block of houses, to be emptied daily, and disinfecting on being emptied. All such plans must be inferior to the cleanliness caused by abundant water. We must learn to remove our filth from our towns, or they will be as unwholesome as they once were. Nothing but abundant water can make the largest city in the world (London) the healthiest of large cities.

The assertion of the Board of Health is that combined works, comprising a water-pipe for the service of each house, a sink, a drain, and a waste-pipe, and a soil pipe or water-closet apparatus, may be laid down and maintained in action at a cost not exceeding on the average three half-pence per week, or less than half the average expense of cleansing the cesspool for any single tenement. This seems borne out by the example of several towns under the care of engineers penetrated with the spirit which dictated the changes. To the above amount has been added water supply, which has increased the sum to threepence per week.

Sewers must certainly not leak, or they must be disinfected. Dr. Angus Smith proposed long ago that they should be disinfected nearly from their sources. In other words, disinfectants should flow through all the great sewers, and so bring them to the rivers in a state where putrefaction is impossible. The advantage of this would be great. When Mr. McDougall was showing his plan of disinfecting sewers to the Board of Works, the smell of the substance he used when he tried it in excess was perceived in the houses along the line of the sewer, showing clearly that the present sewers allow their filthy smells to go into the air of houses. He completely destroyed the sewer smell. To prevent bad air in sewers, some persons, and amongst others some in the Board of Health, have proposed ventilation, and have thus polluted towns with the air which, after all, may be better where it was. To obviate this, they sometimes filter the air through charcoal before allowing it to escape. No plan will succeed but that which, by preventing putrefaction, prevents entirely the formation of foul air. At present all the lines of sewers are unequal; they may all be cleaned by antiputrefactive substances. If every family used them, even the smallest drains would be disinfected with universal benefit. Of course the Thames would cease to putrefy if the larger sewers were all treated in this way.

When the excretions are allowed to accumulate in a town behind the houses, as in Leeds and many other large manufacturing towns, they must of course be periodically removed, as the amount of impure vapor is very much in proportion to the surface exposed. There is little improvement caused by slightly diminishing the solid contents. When removed, it must be taken either to deposits in the town, as at Manchester, or deposits out of the town, as at Paris. It cannot, except in small towns, be removed directly to the land, as the demand is not regular. In both cases the removal is a great grievance, and the places of deposit are unsightly, especially near Paris, at Bondy, where a great district becomes uninhabitable. If removed by water, either the streams must be polluted, or sewers must be carried along the streams very far. If the sewer matter is not disinfected in the sewers, it will flow without disturbing any one; and if not so much diluted with surface matter as at present, it might be put at once on the land, without any one knowing by the smell that it differed from pure water.

Since Edwin Chadwick, C.B., and Dr. Southwood Smith, whether under the name of the Board of Health, or Sanitary Commissioners, or other name, stimulated the country to sanitary purposes, the supply of water and every other progress relating to health has undergone a great change. Professor Clark first showed the advantages of soft water; and, wherever it can be obtained, it is now in used towns. Every town which can obtain it has now a supply of water; and the supply in many is constant. The loss of labor to a family
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where water is obliged to be carried from a well is sometimes equal to that of one person for at least one third of a day. And even with this loss there is an insufficient supply, which adds to the inconveniences of a household, and the loss of comfort and of health. As towns enlarge, and as houses become higher, the necessity for a supply being introduced into houses increases. In Glasgow there is a supply from Loch Katrine, 34 miles distant. The supply in Scotch houses must be taken to the highest story of the houses, on account of the system of living in flats, and because in the large towns almost every family has a water-closet and a bath.

The cleaning of the surface of streets is another important point in sanitary economy. Abundance of water for this purpose would be a great advantage; but the plan is not introduced here. The Whitworth sweeping machine was a good cleanser, but it was very heavy, and the carriage became expensive. Hand sweeping is still resorted to. If disinfecting agents were put into the water-carts which watered the streets, the putrefaction going on there in great abundance would be arrested, and the disinfected matter would flow into the sewers, which would then be free from impure air, and would run into the river in a state that would not corrupt. This was also proposed, in addition to the method alluded to of disinfecting sewers, and by the same persons. After the towns and their immediate neighbourhoods have been purified, it is needful to purify the land. The great sources of malaria are not known; but it is abundantly known that badly-drained land, especially at a high temperature, is productive of malaria; and that even at a moderate temperature malaria causes intermittent attacks. Drainage has greatly removed aque from this country; it has cleared the land; and the atmosphere has become brighter, because the dried land has not produced so many fogs as that which was cold and wet. The clearing of swamps was a labor of Hercules, no less valuable now. The agricultural or money value of land has, at the same time, greatly increased.

Towns.—It has been shown that a death-rate of 22 per thousand yearly prevails in England, but that in large manufacturing towns it rises to 34, and in certain parts of them even to 45, whilst in small and healthy places it is as low as 17, and in some cases even less so. The loss of life is great, and the loss of property also. A great object of sanitary reformers has been to show that to improve health has been to improve property. There can be no doubt of it. Disease causes much loss of time and labor, and diminishes the power of a country in which it exists. We may very fairly calculate from the amount of deaths the amount of disease. To improve our health is to improve our happiness and our wealth, as well as our capacities for both. Although in some country places malaria may cause illness, and ignorance may in various ways induce most unwholesome habits, there is less fear of disease on an average far from a town, because of the tendency of persons to live out of doors, breathing pure air, for in most places it is pure. In towns we are not only apt to be more shut up, and to have less exercise, but we are exposed to all the impurities which arise from the neighborhood of multitudes, as well as from the vapors and gases from manufactures. Many chemists have found it difficult to tell the difference between town and country air, and have denied any difference; but it is now proved abundantly. The very rain of towns where much coal is burnt is so acid, that a drop falling on litmus renders it red. Blood shaken with the air of towns takes a different shade from that shaken with pure air. The air of Manchester contains about 0.0000834 of sulphuric acid, partly sulphuric, into which the impurities of the air by means of a very dilute solution of permanganate of potash. His results are obtained by filling a bottle with the air of the place, merely by pumping the air out and allowing the air around to enter. A little permanganate is poured into the bottle, and it is decolorized; more is added until the color remains. By this means comparative amounts of oxidizable matter are readily measured. A pig-stye required 109 measures; air from the centre of Manchester, on an average 58; air over the Thames, when the putrid stage had just passed, 43; London, 29; after a storm at Camden Town, 12; fields near Manchester, 13; 7; German Ocean, 3; 3; Hospice of St. Bernard, in a fog, 2; Lake of Lucerne, calm, 14. When sulphuric acid and sulphurated hydrogen are present, the action is instantaneous: when organic matters only are present, the result is obtained more slowly. The difference between town and country air is remarkable. The author hopes to make the experiment suitable for daily use in hospitals. The bottle used contains about 100 cubic inches; the solution of permanganate is graduated by a standard solution of oxalic acid, of which 1,000 grams contain 1 of anhydrous oxalic acid. 9 grams of this solution decompose 600 grams of the solution of permanganate.

To prevent impurities in the air of towns is extremely difficult. Manufactures must not be crippled; certainnoxious operations are not allowed, and complaints well substantiated against any offensive works compel their removal. The method of absorbing noxious gases of some kinds is now becoming usual. The coke towers for absorbing muriatic acid began a great change in this respect. They have been used for sulphuric acid itself, nitrous fumes, sulphuric acid, sulphurated hydrogen, &c. In manufacturing towns there is little sulphurated hydrogen—it is decomposed rapidly by the sulphuric acid. A mode of absorb-
ing this latter acid from coal smoke would be a great blessing to all. But this would not remove all the evil; coals send out black soot in such abundance that the whole of a town is darkened, every thing clean is made impure, and the people find that cleaning is a hopeless task. This might readily be burnt, but even then we have other difficulties. Ashes rise up in great amount, and fall down again in a perpetual shower of dust. It is these solid matters as well as the gases which render our towns unwholesome. If the smoke could be washed it would remove all these evils, but the loss of a draught to the fire is then a consequence not yet practically overcome. When coals are burnt with abundance of lime, no sulphur is given off, but the use of this cannot become general. We are very much in want of a more economical and wholesome method of obtaining from coals the power which is in them.

Mr. Spence, of Manchester, proposes to connect all the furnaces of the city with the sewers, and thereby to burn the gases and to ventilate the sewers at the same time. He believes that one chimney will ventilate readily 500 houses, including the house drains and sewers also.

The following advantages to be derived from the drainage of suburban land have been mentioned by the Board of Health:—1. The removal of that excess of moisture which prevents the permeation of the soil by air, and obstructs the free assimilation of nourishing matter by the plants. 2. Facilitating the absorption of manure by the soil, and so diminishing its loss by surface evaporation, and being washed away by heavy rains. 3. Preventing the lowering of the temperature and the chilling of the vegetation, which diminishes the effect of solar warmth, not on the surface only, but at the depth occupied by the roots of plants. 4. Removing obstructions to the free working of the land, arising from the surface being at certain times, from excess of moisture, too soft to be worked upon, and liable to be pecked by cattle. 5. Preventing injuries to cattle or stock, corresponding to the effects produced on human beings by marsh miasms, chills and colds, inducing a general low state of health, and in extreme cases the rot or typhus. 6. Diminishing damp at the foundations of houses, cattle sheds, and farm steadings, which cause their decay and dilapidation, as well as discomfort and disease to inmates and cattle.

The Board of Health, in its excessive desire to remove all refuse by water, has often exaggerated the evils of every other aid to cleanliness. Water is unquestionably the best, but it cannot always be obtained. In some climates it is not to be found in abundance, and in some weather it is only to be had by the use of heat. When the cold is great there is no fear of putrefaction or putrid gases; in warm places, or even in temperate, the use of disinfectants before removing the putrid matter is much to be desired. The Board of Health has not feared to send putrid matter into a river, believing it better there than in the town; it desires the water to be put instantly on the land, and to be disinfected by the land. It is well known that the process of doing this is often offensive. It is also known that large quantities of this matter cannot be disposed of at all times. It has been said that if the liquid were diminished by the rain-fall, it might be manageable. There is another method of diminishing its amount. At Carlisle it was found that the water was almost pure at certain hours of the day, and at all hours of the night. By allowing the more impure only to run into the sewers, the quantity not only becomes manageable, but the quality becomes more valuable. This is in important point, but one which will probably be less apparent in such a place as London, where the changes occurring from hour to hour cannot be so great as in smaller places. In Carlisle the sewage is deodorized and used on the meadows, and a great problem seems there and elsewhere to have begun its solution.

Sanitary economy has proceeded chiefly under the impression that the pollution of the air is the evil most to be dreaded. That this idea is correct there are very many proofs; but that there are numerous other evils affecting our large towns, it is unwise to deny. Polluted air causes damp and close cellars, and unventilated garrets and other rooms, to be unhealthy, as well as all rooms without proper openings, without chimneys, and without openings to the windows. In a word, polluted air rises from close places and dirty places; want of light, too, is an evil under which all living creatures suffer. Great and crowded towns are subject most to all these evils, but in them also the habits of the people come into consideration. In many of the manufacturing towns the people obtain much larger wages than in the country places, but their houses are badly furnished, and their clothes, for every-day at least, are extremely filthy, whilst their love of pleasure is excessive. It is commonly supposed that the love of pleasure exists among the rich, but it is unquestionably one of the greatest evils oppressing the poor in all large towns, because their cultivation of mind has not kept pace with their knowledge of the external appliances of civilization.

A deficient intellectual and moral condition are the great causes both of poverty and bad health, for both go together in almost exact proportions. It must never be expected that pure air alone can make men healthy. The mind, as well as the body, must be freed from irregularities. Abundant wages, which are equal to facilities of health, have rendered our working classes inferior in some cases, both in body and in mind, because they have not
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had education to resist indulgence. These classes will often contrast badly with a poor but cleanly rural population, calm in mind, without a desire for excitement. The subject is here only slightly touched, it needs a volume; sanitary economy, or the method by which man best adapts his place of abode to the conditions of external nature, must ever be a study of the most absorbing interest.—R. A. S.

SCOURING. This art is that which is employed for removing grease spots, &c., from clothes and furniture, which require skill beyond that of the laundry. It is divided into two distinct branches, viz., French and English cleaning. We will first give an outline of English cleaning, although the other (French) has no more to do with the French than the English, except in name; and that is kept because many people would not fancy the things were done properly if done by an English process.

Gentlemen's clothes, such as trousers, coats, &c., are treated in the following manner. They are stretched on a board, and the spots of grease, &c., first taken out by rubbing the spots well with a brush and cold strong soap liquor; they are then done all over with the same, but the grease spots are done first, because they require more rubbing, of course, than the other parts, and when all the substance was wet they would not be so easily distinguished. After treatment with the strong soap liquor, the soap is worked by a weaker soap liquor; the articles are then well washed off with warm water, and treated with ammonia, (if bloomed,) solution of common salt, or dilute acid, according to circumstances. They are then dried, beaten out with a little size, pressed and dried.

Ladies' articles of dress, as shawls, and woollen dresses. — The spots are first removed by rubbing them on the board with very strong soap liquor; they are then put into a strong soap liquor, and well worked about in it; then taken out and treated with a weaker soap liquor, to work out the soap, &c.; rinsed with warm and cold water alternately; treated with solution of common salt or very weak acid, to maintain the colors. They are starched, if necessary, and ironed. Woollen dresses that are taken to pieces are calculated instead of ironing.

Silk dresses, &c., are always taken to pieces, and each piece done separately, and as quickly as possible. If there are any spots of grease, they are taken out first, as above mentioned. Each piece, after the spots are removed, is immediately placed in a strong soap liquor, and well worked about in it, and then into a thinner soap liquor; well washed out with cold water, and treated with solution of common salt, or very weak acid, or both, as required; each piece is then neatly folded and wrung separately, again folded smoothly and placed in dry sheets, and pressed, so as to remove all dampness from them; they are then put into a frame, a little size or sugar and water used to stiffen and glue; lastly, dried while on the frame by a charcoal fire.

Furniture, as curtains, &c. — These things are put into a tub, with a strong cold soap liquor, and well punched about with a large wooden punch made on purpose; and a great deal depends upon this being properly done. They are then treated in the same manner in a weaker soap liquor, well rinsed with water, treated with common salt or weak acid, as required, wrung out, and dried. Woollen furniture will generally require to be treated several times with the first strong soap liquor, to remove the dirt, but for cotton furniture once will generally be sufficient.

Carpets. — These are well beaten, then laid down on the floor of the dye-house, and well scrubbed with strong cold soap liquor, by means of a long-handled brush or broom; then treated with a weaker soap liquor; well rinsed with water, by throwing pails of water over them, and still rubbing with the brush; treated with water, to which a very small quantity of sulphuric acid has been added, to retain the colors; rinsed again, hung up to drain, and then hung up in a warm room to dry.

A great point in this kind of cleaning is to use strong cold soap liquors; and this cannot be done with ordinary soaps, as they congeal when cold, and on this account Field's soap is the principal soap which is used, because it is made from oil, and does not congeal, and I rather expect is made from the olea obtained in the manufacture of composite candles.

French cleaning is what is called dry cleaning. In this process the articles are put into camphene and worked about in it, drained, sheeted, and dried. The camphene dissolves the grease, &c., and does not injure the colors; but when things are very dirty, it does not clean so effectually as the English method. It is, however, the only process that can be employed in some cases, as in cleaning kid gloves.—H. K. B.

SELENITE. Hydrated sulphate of lime. See ALABASTER and GYPSUM.

SEWING MACHINES. The history of these ingenious inventions has been so well told by Professor Willis, in his report on the machinery for woven fabrics of the Paris Exhibition, that we do not hesitate to borrow from it.

At the Paris Exhibition in 1854, fourteen exhibitors came provided with sewing machines. They were of different characters, and have been divided by Mr. Willis into four classes.

Under the first class came the machines in which the needle is passed completely through the stuff, as in hand working: "It is so natural, in the first attempts to make an automatic
imitation of handiwork, that the imitation shall be a slavish one, that we need not be surprised to find the earlier machines contrived to grasp a common needle, push it through the stuff, and pull it out on the other side."

Thomas Stone and James Henderson, and some others, patented machines of this kind, which proved abortive. M. Heßmann exhibited an embroidery machine in 1834, in which "150, more or less, of needles are made to work simultaneously, and embroider each the same flower or device upon a piece of stuff or silk stretched on a frame and guided by a penograph." (See Embroidering Machine.) Several embroidering machines have been from time to time introduced.

The second class of sewing machines was that known as the chain-stitch, or "crochet." This is wrought by a so-called crochet needle, which terminates with a hook; the needle is grasped by the opposite end, and the hook pushed through the stuff, so as to catch hold of a thread below, and, being then withdrawn, brings with it a small loop of the thread; the hook of the needle retaining this loop is then repassed through the stuff at a short distance in advance of the former passage, catches a new loop, and is again withdrawn, bringing with it the second loop, which thus passes through the first. Such a series is called chain-stitch, and may be used either to connect two pieces together, or as an embroidery stitch, for which it is well adapted by its ornamental and braid-like appearance. M. Thimonnier patented in 1830 the first machine of this character. M. Magain was associated with Thimonnier in 1848 in a patent for improvements, and in 1851 it was exhibited in London.

In 1849 Morey and Johnson patented a sewing machine in this country, in which a needle with an eye near the point, perpendicular to the cloth, was combined with a hooked instrument parallel to the cloth, for effecting the same purpose as the crochet needle. Mr. Singer improved on this, and he introduced a contrivance by which his machine forms a kind of knot at every eighth stitch.

The third class of sewing machines is wrought by two threads, and, as the stitch produced by them is known in America as the vail-bag stitch, it may be presumed it was employed by the makers of that article before the introduction of the machine. In the usual mechanical arrangement for its production, a vertical needle having the eye very near the point, is constantly supplied with thread, from a bobbin, and is carried by a bar, which is capable of an up-and-down motion. The cloth being placed below the needle, the latter descends, pierces it, and forms below it a small loop, with the thread carried down by its eye. A small shuttle, which has a horizontal motion beneath the cloth, is now caused to pass through this loop, carrying with it its own thread. The needle rises, but the loop is retained by the shuttle thread. The cloth being next advanced through the space of a stitch, the needle descends again, and a fresh loop is made. This process being repeated along the line of the seam, it results that the upper thread sends down a loop through such needle hole, and that the lower thread passes through all these loops, and thus secures the work. The first machine for producing this stitch was invented by Walter Hind, of New York, in 1834. Several patents for producing this stitch have been obtained. Howe's patent was one of the most practical. Mr. Thomas of London became the possessor of Howe's patent. This was improved; and a new patent obtained in June, 1846, which was modified in December of that year. This machine has been extensively used. This invention, says the patentee, consists in certain novel arrangements of machinery, whereby fabrics of various textures may be sewn together in such a manner as to produce a firm and lasting seam. By this invention a shuttle, when the point of the needle has entered the cloth or other fabric under operation and formed a loop of thread, passes through that loop and leaves a thread on the face of the cloth, by which means the needle when it is withdrawn from the cloth, instead of drawing back the thread with it, leaves a tightened loop on the opposite side of the cloth to that at which it entered. The fabric then passing forward to the distance of the length of the stitch required is again pierced with the needle, and a stitch is in like manner produced. A drawing of this machine is shown in fig. 607, which will be understood from the following description.

1. The needle. Place the needle in the slide 4, with its flat side towards the shuttle, and the grooved side in front. Turn the wheel of the machine round till the line g on the gum-metal slide is level with the line y on the iron cheek. Place the eye g of the needle level with the top of the shuttle box, and screw the needle fast.

2. If the eye is above the box when the marks correspond, the needle is too high; if the eye cannot be seen, the needle is too low.

3. The needle should pass down the centre of the hole in the shuttle box; but if it does not, it can be made to do so by bending.

4. The needle thread runs from the top of the reel, through the rings n, c, and through the eye of the needle.

5. The shuttle. It is necessary that the first coil of cotton be wound closely on the bobbin, or it will be difficult to make it lie side by side like that on ordinary reels. The reels should not be filled above the brass, and the cotton or silk should be free from knots, which sometimes pull the wire out of the shuttle.
6. The thread must run from the under side of the bobbin, round the wire and out through holes Nos. 1, 2, and 3. If the thread is not tight enough, miss No. 3, and let it come out through No. 4 or 5, or it may be drawn through five holes. Put the shuttle in the box, turn the wheel round once, then pull the end of the needle thread and draw up the shuttle thread through the hole in the plate. Place the cloth under the shuttle, and the machine is ready for work. The proper time for turning the work to sew a corner, &c., is when the spring at the top is lifted off.

7. The length of stitch is regulated by the screw \( v \) at back of machine.

8. The tightness of the needle thread is regulated by the screw \( r \).

9. The tightness of the shuttle thread is regulated by passing the thread through more or less holes.

10. The quantity of thread pulled off the reel for each stitch is regulated by the position of the piece of brass \( n \). The lower the hole at its end the greater the quantity pulled off: when the cloth is thick, more thread is used, and the end of the brass \( n \) should be lowered; when thin, raised. It should be in such a position that the trumpet \( c \) is drawn nearly down to the pin on the slide when the shuttle passes through the loop.

A patent was obtained by John Thomas Jones, of Glasgow, in February, 1859, for a sewing machine presenting many novelties and improvements. Mr. Jones' patent well explains his machine; we therefore transfer his description to our pages.

The machine consists, under one modification, of an open frame, having a platform top upon which the sewing or stitching operations are carried on. Beneath this platform, and near one end of it, is a short transverse horizontal first motion shaft running in bearings in the framing and carrying a long crank, a connecting rod from which is jointed at its opposite end, directly to the shuttle driver or slide piece, working in a horizontal guide recess beneath the opposite or front end of the platform or table. The first motion shaft has also another and shorter crank upon it, the stud pin of which is connected to the pin of the longer crank by an overhanging link piece, provision being made for the adjustment of the relative positions of the two cranks as regards their sequence of revolution. It is this shorter crank which actuates the needle movement, the pin being entered into a differentially slotted or operated cam piece, forming the pendent lower end of a bent lever, working on a stud centre, in the interior of the overhead bracket or pillar arm of the framing. The centre on which this lever works is in the horizontal part of the overhead bracket arm, and its opposite or free working end has a rectangular slot in it to embrace a rectangular block of metal working freely upon a lateral centre stud upon the vertical needle-carrying bar.

In this way the needle has imparted to it a differential reciprocatory vertical movement, the peculiar connection of the needle bar with the actuating lever having the effect of marking the needle in the most accurate manner, and preventing jarring and wear. These are the whole of the primary movements for working the stitches, which may be of various kinds, as made up from the combined action of the needle and shuttle, or thread-carrier; the form of the slotted piece or operated cam in the end of the needle lever, being variable to suit any required peculiarity of needle movement, the main elements of which are a direct up-and-down motion without a stop or rest, until at the termination of the down stroke, when a short rise takes place, succeeded by a rest to allow of the due looping and stitching of the thread. The feed of the fabric to be sewed is effected by the operation of a short verti-
SILVER, ASSAY FOR.

cal lever piece with a cranked and slotted lower end, where it is set on a fixed stud in the framing. This feed lever has a roughened or toothed upper end, the teeth or asperities being set or inclined in the direction of the fabric's traverse. After each stitching action, the feed lever being lowered just beneath the operating level, is raised up so as to press firmly against the under side of the fabric, and nip it between the stationary spring pressed above. This elevation of the roughened face is effected by the traverse of the shuttle carrier, which at its back stroke comes against the inclined tail of a short horizontal lever set on a stud in the framing, and having its opposite bent end bearing against the lower end of the feed lever, at the part where it is carried by its slot upon the holding stud. At the commencement of the return of the shuttle, an inclined piece upon the shuttle carrier bears against a lateral stud upon one end of a short rocking or oscillatory shaft set in bearings in the framing, the other end of the shaft having a lever arm bearing against the side of the feed lever. In this way the feed lever is traversed forward in its elevated position, carrying forward the fabric for the succeeding stitch. The adjustment of the spring presser is effected by an upper screw in the end of the bracket arm of the framing, the lower end of the screw bearing upon a lateral pressing piece which rests or shuts on the top end of a flattened helical spring upon the presser bar. The latter can be set up clear out of work by means of a small cam lever set on a stud in the stationary guide of the presser bar, the cam bearing against a lateral stud in the bar, so that by setting the lever up or down, the cam is correspondingly turned, and the lever set up or down, as required. The actual pressing or resisting foot of the bar is a bent piece of metal screwed on to the bar, and being thus removable to allow of various forms of foot guides, or presser surface pieces, being put on to suit varieties of forms of stitching.

This machine, or a modification of it, is available for working a duplex, or other stitching action, without involving further modification of the prime movers. In working a duplex arrangement, two needles and two shuttles are used, each needle and shuttle working independently, so as to allow of sewing in two different and independent lines with one set of actuating parts. To aid the shuttle action there is attached to its side a flat curved blade spring, one end of which is free, but hooked into a hole in the body of the shuttle. Thus, as the shuttle traverses forward, the sewing thread is drawn beneath the hooked end portion of the spring, so as to be nipped against the shuttle. The thread is thus held, and the proper loop is secured at the part immediately outside the nipped portion. With this arrangement the needle can never work on the wrong side of the shuttle thread. Provision is also made for securing an independent shuttle thread controller. This is a nipper or retainer worked from any convenient part of the mechanism, but entirely independent of the shuttle movement. This may be arranged in various ways, the object being the variable and efficient control or retention of the thread, without interfering in any way with the fixed and determined action of the shuttle. Instead of fixing a horizontal shuttle race, or guide track, in the framing, the shuttle driver is itself made the race or carrier, so as to secure both offices in one detail or arrangement. A hook or finger, actuated by any convenient part of the movement, is also used for retaining the needle thread for any desired time after being passed through the fabric; this facilitates the movement or action of the needle bar. The shuttle race, when one is used, is made quite independent of the machine, so that it can be changed at any time to suit various sized shuttles by merely slipping in or taking out the part. The portion of the framing carrying the shuttle race is cast in one piece with the main body of the platform, but the table or plate on which the stitching takes place is a loose piece slotted down the middle for the working movements, and fitted into its position by pins cast upon it, and entered into corresponding recesses in the main base.

There exists a fourth class of sewing machines, which produce more complex stitches than the preceding. These are formed by sewing two threads, which mutually interface each other in chain stitch, so as to avoid the unravelling to which the simple chain stitch is subject, and are also intended to meet an objection which is urged against the shuttle stitch machines, on the ground that, as the shuttle must be small to enable it to pass through the loop formed by the needle thread, so the bobbin carried by the shuttle can only obtain a moderate length of thread. Thus the operation is stopped at short intervals to supply fresh bobbins to the shuttle. Several patents have been obtained for compound chain stitch machines; two in America, in 1851 and 1852, by Grover and Baker; another in 1852 by Avery; and another by M. Journaux Le Blond.

Mr. Willis, in concluding his report, very justly remarks, "In England, as in France, all the most promising American patents have been repudiated, and the use of the machine appears to be slowly and gradually extending itself. The sewing machine is doubtless yet in its infancy; but it has acquired so prominent a position, and shown itself so useful, as to deserve the time and attention of able mechanists. Its imperfections will therefore be, if possible, gradually removed, and it may take its place in the series of manufacturing mechanisms as a most useful agent."

SILVER, ASSAY FOR, Estimation of silver contained in lead ores. Many varieties
of lead ore contain silver, and it is consequently necessary, in order to judge of their commercial value, to ascertain the exact amount of this metal which they afford. This is effected by the process of cupellation: an operation founded on the fact that when an alloy of lead and silver is exposed to a current of air, when in a state of fusion, the silver neither gives off perceptible vapors nor becomes sensibly oxidized, whilst the lead rapidly absorbs oxygen and becomes converted into a fusible oxide.

In order therefore to separate the silver that may be present in buttons resulting from ordinary lead assays, it is only necessary to expose them on some suitable porous medium, to such a temperature as will rapidly oxidize the lead. The litharge produced is absorbed by the porous body on which the assay is supported, and nothing but a small button of silver ultimately remains on the test. These supports or cupels are made of bone-ash, slightly moistened with a little water, and consolidated by being pressed into a mould. The furnace employed for this purpose is described in the article Assay, vol. i.; as is also the muffe or D-shaped retort in which the cupels are heated.

As soon as the muffe has become red hot, six or eight cupels that have been drying in the mouth of the opening are introduced by means of proper tongs, and the bottom of the muffe is covered with a thin layer of bone-ash, in order to prevent its being attacked in case of any portion of litharge coming in contact with it during the progress of the subsequent operations. The open end of the muffe is now closed by means of a proper door, and the cupels are thus rapidly heated to the temperature of the muffe itself. When this has been effected the door is removed, and into each of the cupels is introduced by the aid of slender steel tongs a button of the lead to be assayed. The mouth of the muffe is again closed during a few minutes to facilitate the fusion of the alloy, and on its removal each of the cupels will be found to contain a bright metallic globule, in which state the assay is said to be uncovered. The lead is now quickly converted into litharge, which is absorbed by the cupel as fast as it is produced, whilst at the same time there arises a white vapor that fills the muffe and is gradually carried off by the door and through the openings in the sides and end. A circular stain is at the same time formed around the globule of metal, which gradually extends and penetrates into the substance of the cupel. When nearly the whole of the lead has thus been removed, the remaining bead of alloy appears to become agitated by a rapid motion, which seems to make it revolve with great rapidity. At this stage the motion will be observed suddenly to cease, and the button, after having for an instant emitted a bright flash of light, becomes incommoable. This is called the brightening of the assay, and a button of silver now remains on the cupel.

If the cupel were now abruptly removed from the muffe, the metallic globule would be liable to segregate, by which a portion of the metal might be thrown off, and a certain amount of loss be thereby entailed. To prevent this, the cupel in which the assay has brightened should be immediately covered by another, kept red hot for that purpose. The two are now gradually withdrawn together, and, after having sufficiently cooled, the upper cupel is removed, and the globule of silver detached and weighed.

From the fact that silver becomes sensibly volatile at very elevated temperatures, it becomes necessary to make cupellations of this metal at the lowest possible heat at which they can be effected. The temperature best fitted for this operation is obtained when the muffe is at a full red heat, and the vapors which arise from the assays are gradually away, and are finally removed by the draught. When the muffe is heated to whiteness, and the vapors rise to the top of the arch, the heat is too great; and when, on the contrary, the flames lie over the bottom, and the sides of the openings in the muffe begin to dark, either a little more fuel must be added or the draught increased.

If an assay has been properly conducted, the button of silver obtained is round, bright, and smooth on its upper surface, and beneath should be crystalline and of a dead-white color; it is easily removed from the cupel, and readily freed from litharge. The globule is now laid hold of by a pair of fine pliers and flattened on a small steel anvil, by which the oxide of lead which may have attached itself to it, becomes pulverized, and is removed by rubbing with a small hard brush. The flattened disc is then examined, in order to be sure that it is perfectly clean, and afterward weighed in a balance capable of turning with one-thousandth of a grain.

The fuel employed consists of hard coke broken into small pieces.

When the ores of lead, in addition to silver, contain gold, the button remaining on the cupel is an alloy of those metals.

For commercial purposes, the silver contained in any given ore or alloy is estimated in ounces, pennyweights, and grains, one ton of ore or alloy being usually taken as the standard of unit.

Assay of silver ores not containing lead.—In the assay of ores belonging to this class, it is usual to obtain the silver they afford in the form of an alloy with lead; and this is subsequently passed to the cupel in the ordinary way.

Ores of silver in which the metals exist in the form of oxides are commonly fused with a mixture of litharge, red lead, and powdered charcoal, by which an alloy of lead is obtain-
ed, which is afterwards treated by cupellation. The amount of litharge employed must be varied according to circumstances, as the resulting button should not be too small, since in that case a portion of the silver might be lost in the slag; nor too large, as the cupellation would then occupy a long time, and a loss through volatilization be the result.

In most cases, if 400 grains of ore be operated on, a button of 200 grains will be a convenient weight for cupellation; this may be obtained by the addition of 400 grains of litharge, and from 7 to 8 grains of pulverised charcoal. This is to be well mixed with 200 grains of carbonate of soda, and introduced into an earthen crucible, of which it should not fill more than one-half the capacity. This is covered by a layer of borax, and fused in the assay furnace, taking care to remove it from the fire as soon as a perfectly liquid slag has been obtained, since the unreduced litharge might otherwise cut through the crucible and spoil the assay. When cold, the pot is broken, and the button cupelled in the ordinary way.

In this, and all other similar experiments, it is necessary to ascertain the proportion of silver contained in the lead obtained from the litharge used, in order to make the requisite deduction from the results obtained. When fine litharge is employed the resulting lead contains so small an amount of silver, that for many commercial purposes it may be disregarded.

When other minerals than oxides are to be examined, the addition of charcoal becomes in many cases unnecessary, since litharge readily attacks all the sulphides, arsenio-sulphides, &c., and oxidizes many of their constituents, whilst a proportionate quantity of metallic lead is set free. The slags thus formed contain the excess of litharge, and the button of alloy obtained is cupelled. The proportion of oxide of lead to be added to ores of this description varies in accordance with the amounts of oxidizable substances present; but it must always be added in excess in order to prevent any chance of loss of silver from the action of sulphides in the slags.

The only objection to this method of assay is the large quantity of lead produced for cupellation—since iron pyrites afford by the reduction of the litharge 8¼ parts of lead, whilst sulphide of antimony and grey copper ore yield from 6 to 7 parts. This inconvenience may be obviated by the previous oxidation of the mineral, either by roasting, or by the aid of nitre, by the judicious employment of which buttons of almost any required weight may be obtained.

Should this reagent be employed in excess, it would cause the oxidation of all the metallic and combustible substances present, not even excepting the silver.

When, however, the mixture contains at the same time a large excess of litharge and the quantity of nitre added is not sufficient to decompose the whole of the sulphides, a reaction takes place between the undecomposed sulphide and the oxide of lead added, which gives rise to the formation of metallic lead, and this combining with the silver, affords a button of alloy, which may be treated by cupellation.

The quantity of nitre to be used for this purpose will depend on the nature and richness of the ore; it is under examination; but it must be remembered that 2½ parts of nitre will decompose and completely oxidize pure iron pyrites, whilst ½ and ⅓s of its weight are in the case of sulphide of antimony and galena respectively sufficient.

In cases when the excess of sulphur present is very great, a partial roasting of the ore is preferable to the addition of a large quantity of nitre.

Instead of operating according to any of the processes above described, it is sometimes found advantageous to expel the whole of the arsenic and sulphur by a careful roaring, and then to fuse the residue with a mixture of litharge, carbonate of soda, and borax, taking care to add a sufficient amount of some reducing flux to obtain a button of convenient size. When in addition to silver the mineral operated on contains gold, the button obtained by cupellation will consist of a mixture of these metals, which may be separated by the aid of nitric acid.

Scorification.—Instead of operations as above described, silver ores are sometimes treated by scorification. In that case, they are mixed with granulated lead and exposed in small refractory saucers to a strong heat in an ordinary muffle furnace. After a sufficient amount of the lead has become oxidized, and the resulting litharge has formed a fusible slag with the gangue of the ore, the metallic lead is poured into a suitable mould, and afterwards subjected to cupellation. When the granulated lead employed for this purpose contains silver, due allowance for its presence must be made in the result obtained.

Simple process for the reduction silver to a metallic state by means of sugar.—The silver of coin is first reduced to the state of chloride, and the weight of the alloy thus ascertained; the chloride, after having been well washed and freed from copper, is to be put into a stoppered vessel; a quantity of refined sugar, or sugar-candy, is then added, equal in weight to the alloy. This is mixed with an equal volume of a solution, composed of 60 grammes of good hydrate of potash, and 150 grammes of distilled water, which will yield a solution of potash of 25° Beaumé, or thereabouts; after closing the bottle the mixture is to be agitated, and then left for 24 hours, shaking it occasionally, to favor the reaction. After
this period has elapsed, it is to be washed several times, until the last washings, filtered, are not affected by nitrate of silver—a test which should be preceded by that of red litmus paper, which ought not to become blue, or show any change whatever. This done, the contents of the bottle are to be transferred to a porcelain capsule, by the help of a little distilled water; then, after being allowed to deposit, the excess of liquid is poured off, and the sliver dried in a stove.

By these means we obtain that to which Dr. Ure gave the name of \textit{gray silver}. This sliver consists of some bright spangles, which become more brilliant on friction. It does not contain any impurities, with the exception of a small quantity of oxide, and a few atoms of chloride of silver. This latter produces a slight turbidity in the liquor, when dissolved in perfectly pure nitric acid, and diluted with distilled water. This turbidity does not, however, prevent the formation of pure nitrate of silver; as the chloride being only in suspension in the liquid, it is sufficient to filter it on a small portion of well washed asbestos, in order to obtain an unobjectionable liquor. The nitrate of silver will not contain any trace of other metals, as none are used in the reduction of the chloride of silver, and by the reduction of this salt the silver is completely separated from the iron and copper which the solution might contain. Thus the nitric acid of commerce may be employed, without inconvenience, for dissolving the alloy.

The \textit{gray silver} almost always contains a small quantity of oxide; this is easily verified by the addition of ammonia, which, after digestion on the metal and filtration, produces a slight turbidity on adding nitric acid, which is caused by the separation of the dissolved chloride of silver; the turbidity is then increased by the addition of a small quantity of chloride of sodium to the nitrate of ammonia previously formed; thus, then, is the oxide of silver dissolved in the liquor in the state of ammoniacal nitrate, which is precipitated in the form of insoluble chloride.

Oxide of silver not being an impurity in the uses to which pure silver is applied in laboratories, we may consider the \textit{gray silver} obtained in the manner above described as pure and with less loss than any of those prepared up to the present time, by the reduction of chloride of silver; \textit{and without the necessity of melting, a troublesome operation}, and one of much inconvenience in a laboratory.

\textbf{SOAP} is a chemical compound, manufactured on a very extensive scale, forming, accordingly, a considerable article of commerce. It is a compound resulting from the combination of certain constituents derived from fats, oils, grease of various kinds, both animal and vegetable, with certain saltifiable bases, which, in detergent soaps, are potash or soda. Oils and fats consist chiefly of oleine and stearine, as in tallow, suet, and several vegetable fats; of margarine, which occurs in animal fats, in butter, in olive and other vegetable oils; of palm-tine, which is found in palm oil, and so on with various other immediate principles, according to the nature of the fats and oils employed by the soap-maker. Natural fatty substances, however, are never exclusively formed of one of these principles; but are, on the contrary, composed of several of them in various proportions, oleine alone being a constant constituent in all of them.

Natural or neutral fats and oils, chemically considered, are really salts, sometimes called "glycerydes," that is to say, are combinations of acids, oleic, stearic, margaric acid, &c., with the oxide of a hypothetical radical glyceryle, (sweet principle of oils.)

\textit{Stearine} being, therefore, a combination of stearic acid with oxide of glyceryle, is a stearate of oxide of glyceryle.

\textit{Oleine} is a combination of oleic acid with oxide of glyceryle, and is, therefore, an oleate of oxide of glyceryle.

\textit{Margarine} is a combination of margaric acid and oxide of glyceryle, and is, therefore, a margarate of oxide of glyceryle, and so on with the other constituents of fats and oils.

\textit{Glycerine} is a combination of oxide of glyceryle with water, which, in that case, plays the part of an acid to form a hydrate of oxide of glyceryle, (glycerine.)

Now, when neutral fats (namely, oleine, stearine, margarine, &c., or the fats or oils which they constitute) are treated by solutions of caustic alkalies, such as potash or soda, their constituents react upon each other, and combine with the potash or soda; and provided too great an excess of alkali has not been used, the fat or oil dissolves in the alkaline solution into a syrupy liquid, which on cooling forms a gelatinous mass, which is nothing else than an aqueous solution of soap mixed with the glycerine, which the treatment has set free.

The following equation, in which, for the sake of simplicity, one of these principles only, stearine and soda dissolved in water, is taken as an example, will clearly illustrate this interesting reaction:

\begin{equation}
\text{Stearine.} \\
\text{Stearate of oxide of glyceryle} + \text{soda} + \text{water} = \text{stearate of soda} + \text{hydrate of oxide of glyceryle}
\end{equation}

hard soap. \quad \text{glycerine.}
In the same way:—

\[
\text{Oleine.} \\
\text{Olate of oxide of glyceryl-+soda + water = olate of soda+hydrate of oxide of glyceryl}
\]

hard soap. 
glycerine.

and so on all the immediate principles of which the fat or oil employed is composed, splitting, that is to say, separating from this oxide of glyceryle to form a stearate, oleate, margarate, palmitate, &c, of soda or of potash, and glycerine, (hydrate of oxide of glyceryle.) 

Soaps made with soda are hard; those made with potash are soft; the degree of hardness being so much greater as the melting point of the fats employed in their manufacture is higher; hence the more oleine a fatty matter contains, the softer the soap made with it will be, and vice versa. The softest soap, therefore, would be that made altogether with oleine (oleic acid) and potash (olate of potash); the hardest would be that made with stearine and soda, (stearate of soda.)

The fats or oils employed for the manufacture of soaps, are tallow, suet, palm oil, cocoanut oil, kitchen fat, bone grease, horse oil or fat, hard, butter, train oil, seal oil, and other fish oils, rape oil, poppy oil, linseed and hempseed oil, olive oil, oil of almonds, sesame, and ground nut oil, and resin. This last substance, though very soluble in alkaline menstrua, is not however, susceptible, like fats, of being transformed into an acid, and will not, of course, saponify or form a proper soap by itself. The more caustic the alkali the less consistency has the resinous compound which is made with it. The employ of caustic alkalis, however, is not necessary with it, since it dissolves readily in aqueous solutions of carbonated alkalis; but even with carbonate of soda it forms only a viscid mass, owing to its great affinity for water, so that even after having been artificially dried in an oven, and then reduced to a great extent hard, the mass liquefies again spontaneously by exposure, and returns to the soft state. The drying oils, such as those of linseed and poppy, produce the softest soaps. We said that, by boiling fats or oils with an aqueous solution of potash or of soda, a solution of soap was produced. The object of the soap-maker is to obtain the soap thus produced in a solid form, which is done by boiling the soapy mass so as to evaporate the excess of water to such a point that the soap may separate from the concentrated liquor and float on the surface thereof in a melted state, or by an admixture of common salt, soap being insoluble in eyes of a certain strength of degree of concentration, and in solutions of common salts of a certain strength, the glycerine remaining, of course, in solution in the liquor below the separated soap. Such is the theory of soap-making; but the words operamini followed by practical soap-makers will be described presently.

On the Continent olive oil, mixed with about one-fifth of rape oil, is principally used in making hard soap. This addition of rape oil is always resorted to, because olive oil alone yields a soap so hard and so compact that it dissolves only with difficulty and slowly in water, which is not the case with rape oil and other oils of a similar nature, that is to say, with oils which become thick and viscid by exposure, and which on that account are called drying oils; experience having taught that the oils which dry the soonest by exposure, yield with soda a softer soap than that made with oils which, like olive oil, remain limpid for a long period under the influence of the air. The admixture of rape oil has, therefore, the effect of modifying the degree of hardness of the soap, and, therefore, of promoting its solubility. In England tallow is used instead of olive oil, the soap resulting from its treatment with soda is known under the name of engd soap, and is remarkable for the extreme difficulty with which it dissolves in water. The small white cubic, waxy, stubborn masses, which until a few years were generally met with on the washing-stand of bedrooms in hotels, and which for an indefinite period passed on from traveller to traveller, each in turn unsuccessfully attempting, by various devices and cunning immersions in water, to coax it into a lather, is engd soap. Rape or linseed oil, added in certain proportions to tallow, would modify this extreme hardness and difficult solubility; but it is now the general practice to qualify the tallow with cocoa-nut oil—an oil, which, converted into soap, has the property of absorbing incredible quantities of water, so that the soap into the manufacture of which it has entered lathers immediately. Cocoa-nut oil, however, acquires by saponification a most disagreeable odor, (due to the formation of caprylic acid,) which it imparts to all the soaps in the manufacture of which it enters—an odor which persists in spite of any perfume which may be added to mask it.

The admixture of one-fourth or one-fifth of resin with tallow, in the process of saponification, modifies also the hardness and considerably increases the solubility of engd soap, and this fact constitutes the best yellow soap.

I said that soap was more or less hard in proportion as the melting point of the fats employed in its manufacture was higher or lower. There are certain fatty substances, technically called weak goods, such as kitchen fat, bone fat, horse oil, &c, which could hardly be
used alone, still less with resin, the soap which they yield being too soft, and melting or dissolving away too rapidly in the washing-tub. This led me to think, that if a means could be devised of artificially hardening soap, a larger class of oleaginous and fatty substances could be rendered available, at any rate to a greater extent than they hitherto had been, and that, by thus extending the resources of the soap boiler, he should be enabled to produce a good and useful soap from the cheapest materials, and thus convert soaps of little commercial value into useful and economical products.

In making experiments with this view, I found that the introduction of a small quantity of melted crystals or sulphate of soda into the soap answered the purpose admirably, and that the salt, in recrystallizing, imparted to the soap, which otherwise would have been soft, a desirable hardness, and prevented its being wasted in the tub. The use of sulphate of soda acts, therefore, inversely, like the addition of rape oil, or linseed oil, or of resin to tailor, in the manufacture of soap. This process, which I patented in 1841, has been, since the removal of the duties on soap, extensively employed by soap-makers, and continues to be highly approved of by the public.

Manufacture of mottled soap.—Soda which contains sulphurets is preferred for making the mottled or marbled soap, whereas the desulphurized soda makes the best white curd soap. Mottling is usually given in the London soap-works, by introducing into the nearly finished soap in the pan a certain quantity of the strong lye of crude soda, through the rose spout of a watering-can. The dense sulphurated liquor, in descending through the pasty mass, causes the marbled appearance. In France a small quantity of solution of sulphate of iron is added during the boiling of the soap, or rather with the first service of the lye. The alkali acts the acid of the sulphate, and sets the protoxide of iron free to mingle with the paste, to absorb more or less oxygen, and to produce thereby a variety of tints. A portion of oxide combines also with the stearine to form a metallic soap. When the oxide passes into the red state, it gives the tint called manteau Isabelle. As soon as the muller has broken the paste, and made it pervious in all directions, he ceases to push his rake from right to left, but only plunges it perpendicularly till he reaches the lye; then he raises it suddenly in a vertical line, making it act like the stroke of a piston in a pump, whereby he lifts some of the lye, and spreads it over the surface of the paste. In its subsequent descent through the numerous fissures and channels on its way to the bottom of the pan, the colored lye impregnates the soapy particles in various forms and degrees, whence a varied marbling results.

The best and most esteemed soap on the Continent is that known under the name of Marseilles soap, and it differs from the English mottled soap by a different disposition of the mottling, which in that soap is granitic instead of being streaky. It has also an agreeable odor, somewhat resembling that of the violet, whereas the English mottled soap, generally made of very coarse kitchen and bone fat, has an odor which reminds one of the fat employed. The best English mottled soap in which tallow is employed, has no unpleasant smell, and if bleached palm oil has been used it acquires an agreeable odor, analogous to that of the Marseilles soap, which is made of olive oil alone, or mixed with rape or other grain or seed oil, which, however, seldom exceeds 10 per cent.; for otherwise it would not have the due proportion of blue to the white, which is characteristic of soap made of genuine olive oil, the mottling becoming more closely granular when an undue proportion of grain has been used, a sign of depreciation which the dealers are perfectly well acquainted with, and of which they at once avail themselves, to compel the maker to reduce his price.

Pelouze and Frénay, in their Traité de chimie générale, give the following reliable observations:

"The best olive oil for the use of the soap-maker is Provence oil; that of Aix comes next; it is cheaper, but the same weight of it yields less soap than the other, and the latter has then a slight lemon yellow tinge. The oil from Calabria contains less margarine, and yields a softer soap.

"Two kinds of soda ash are used in Marseilles, the soft soda (soude done) and the salted soda (soude salée), which contain a large quantity of common salt.

"To prepare the lye, the soft soda previously reduced into small lumps is mixed with 12 per cent. of slaked lime, and shovelled up into tanks of masonry of about 2 cubic yards' capacity, called barquieux, and the exhaustion of the mass with water gives lyes of various degrees of strength.

"The lye marking 12" is used for the first treatment, or empâtage of the oil, which is then submitted to a second and third treatment with a lye marking 15° or 20°, the object of which is to close the grains of the emulsive mass in process of saponification, (serve l'empâtage.) The operation requires about twenty-four hours. During all the time of that operation a workman is constantly agitating the boiling mixture of the oil and lye by means of a long rake or crutch, called râble. The empâtage is generally practised in large conical tanks of masonry terminated at bottom by a copper pan, and capable of containing 12 or 13 tons of made soap, and the operation proceeds so much the more rapidly, as the soda lye employed contains less common salt; whereas soft soda lye (soude done) must be used at the beginning, as we said."
"The next operation is that called *relavage*, the object of which is to separate the large quantity of water which has been used to facilitate the *empilage*. This separation of the water, or *relavage*, is effected by means of salted soda, (that is to say, of soda ash, containing a good deal of common salt), of which as much is dissolved in water as will make a lye marking 20° or 25°. This salted lye is then gradually poured by a workman on the surface of the saponifying goods in the copper, while another workman is diffusing it in the mass by stirring the whole with a rake or crutch.

The immediate effect of the salt thus added is to separate from the soapy mass the water in which it was dissolved, and which gave it a homogeneous and syrupy appearance, and to coagulate it, the soap being thereby curded or coagulated, and converted into a multitude of granules floating among the excess of water in which they were dissolved, and which the salt has separated. The whole being then left at rest for two or three hours, in order to give the grains of soap time to rise and agglomerate at the surface, a workman proceeds to the *épinage*, an operation which consists in withdrawing the liquid portion by removing a wooden plug placed at the lower part of the boiler."

In this country the *épinage* is generally performed by means of an iron pump plunging through the soap down to the pan at the bottom of the copper.

This *spuent lye*, in well-conducted factories, retains but little alkali, and is generally thrown away; but as it contains a rather large quantity of salt, which, in France, is an expensive article, it might be, and is sometimes, kept and used for preparing fresh lyes.

After the first *épinage*, the soap is treated twice again with salt lye, followed of course by two *épinages*; but as the salt lye used in these two operations is not exhausted, it is always kept for preparing fresh lyes.

The cleaning, that is to say, the removing of the soap into the frames, takes place on the third day, at which time the operation called *madrage* is performed. For that purpose a plank is thrown across the boiler or copper, and two or three men standing on it, and therefore over the soapy mass in the copper, proceed to stir it up for two or three hours, by means of long crutches, which they alternately move up and down through it, the object being to keep the grains of soap well diffused through the liquid, while lyes marking only 8° or 10°, or ordinary water, as the case may be, being sprinkled from time to time into the mass, until the grains of soap have reabsorbed a sufficient quantity of water and have swollen to such a size as to have a specific gravity very little greater than that of the liquid among which they float about. A skilful workman knows by the appearance of the soap grains whether he should use alkaline lyes or simply water, and this is indeed a most important point in the manufacture of *Marseilles* soap, for upon it the success of the operation depends in a commercial point of view; that is to say, all things being equal in other respects, a profit or loss on the batch of soap made will ensue. In effect, if too much water has been added the soap will lose either the whole, or too great a portion of its *mottling*; that is to say, the result will be either a dingy white card, or a soap in which the white portions will predominate to too great an extent over the blue streaks, a circumstance which so far deteriorates the market value, the buyer shrewdly suspecting then that he would pay for water the price of soap. If, on the contrary, a sufficient quantity of water has not been added, the soap grains remaining hard and dry, will form more or less friable, thereby causing also a deterioration of price, the buyer knowing that such soap, by crumbling into small pieces every time he has to cut it with his knife in selling it to his customers, will considerably reduce his profit, or perhaps even entail a positive loss to him.

In the best conditions, that is to say, by employing the best Gallipoli oil for the purpose of producing Marseilles soap of first quality, 100 cwt. of olive oil yield 175 cwt. of mottled soap; by using mixtures of olive and rape or other seed oils, the yield of soap is reduced to 170, or even less; in either case the yield is reduced by 5 or 6 per cent., when old or fermented is employed instead of new good oil. The manufacturing expenses are calculated at Marseilles at the rate of 17f. 25c. (nearly 13s. and 10d.) per 100 grammes of fatty matter employed, which require 72 grammes of soda for their saponification.

Mottled soap has a marbled, or streaky appearance, that is to say, it has veins of a bluish color, and resembling granite in their disposition or arrangement. The size and number of these veins or speckles, and the proportion which they bear to the white ground of the soap, depend not only on the more or less rapid cooling of the soap after it has been cleansed, that is, transferred from the copper to the frame, but also on the quality and kind of the fat, grease, or oil employed, and on the manner in which it has been treated in the copper. A soap which has not been sufficiently boiled at the last stage of the manufacture is always tender. The blue or slate-color of the streaks or veins of mottled soap is due to the presence of an alumina-ferruginous soap interposed in the mass, and frequently also to that of sulphuret of iron, which is produced by the reaction of the alkaline sulphures contained in the soda lye upon the iron, derived from the soda ash itself, and from the iron pans and other utensils employed in the manufacture, or which is even purposely introduced in the state of solution of protosulphate of iron. This introduction, however, is never
resorted to, I believe, in this country. The veins or streaks disappear from the surface to the centre by keeping, because the iron becomes gradually peroxided. A well-manufactured molified soap cannot contain more than 33, 34, or at most 35 per cent. of water, whereas genuine curd soap contains 45, and yellow soap at least 52 per cent. of water, and sometimes considerably more than that. It is evident, in effect, that the motting being due to the presence of sublurate of iron held in the state partly of demisolution and of suspension, the addition of water would cause the coloring substances to subside, and a white, uncolored, or fitted soap would be the result. This addition of water, technically called *fitting*, is made when the object of the manufacturer is to obtain a unicolored soap, whether it be curd or yellow soap. After *fitting*, the soap contains, therefore, an additional quantity of water, which sometimes amounts to 55 per cent.: the interest of the consumer would, therefore, closely be to buy motled soap in preference to yellow or white soap; the motting; when not artificially imitated, being a sure criterion of genuineness; for the addition of water, or of any other substance, would, as was just said, infallibly destroy the motting. To yellow or curd soap, on the contrary, incredible quantities of water may be added. I have known five pails of water (15 gallons) added to a frame (10 cwt.) of already fitted soap, so that the soap, by this treatment, contained upwards of 60 per cent. of water, to which common salt had previously been added. The proportion of water in fitted soap has also been augmented, in some instances, by boiling the soap in high-pressure boilers before *cleansing*. As cocoa-nut oil has the property of absorbing one-third more water, when made into soap, than any other material, its consumption by the soap-maker has, within the last fifteen or twenty years, augmented to an extraordinary extent; and, moreover, the patent taken in 1857 by Messrs. Blake and Maxwell, of Liverpool, for the invention of Mr. Kottula, which we shall describe presently, has, I believe, increased the demand for that species of oil in a notable degree. We said that the motting, inasmuch as it was indicative of genuineness, was the more economical soap to buy; unfortunately motted soap has the drawback of not being so readily soluble as yellow soap, and the goods washed with it are more difficult to rinse; but the process patented by Messrs. Blake and Maxwell enabling the manufacturer to manufacture with cocoa-nut oil a soap to which the motting is artificially imparted, by means of ultramarine, black or brown oxide of manganese, in such a perfect manner as almost to defy detection, motting has thus ceased to be a safe outward sign of genuineness, as far as regards the article which it pretends to represent. That description of soap, however, has specific qualities; it is almost perfectly neutral, and it will not bear more than a definite proportion of water; so that, although it contains more of that liquid than ordinary molled soap,—more than a certain fixed quantity cannot be forced into it; so that it also forms a standard soap, like the ordinary molled, although that standard is different from, and inferior to, the latter. The process in question is briefly as follows:—Take 80 cwt. of palm oil, made into soap in the usual way, with two changes of lye, grained with strong lye, or lye in the usual manner, but so that the lye leaves the curd perfectly free; pump the spent lye away, and add 32 cwt. of cocoa-nut oil, 60 cwt. of lye, at 20° of Beamé's anemeter, and then gradually 14 cwt. of lye, at 14° Beamé's anemeter, until the whole mass is well saponified. Put now from 6 to 7 lbs. of ultramarine in water, or weak lye, stir the whole well, and pour it into the soap through the rose of a watering pot; boil the whole for about half an hour, or an hour, and cleanse it in the ordinary wooden frames, or in iron frames surrounded by motting, or other covering, so that the soap may not cool too rapidly; the above proportions will yield 212 cwt. of soap, with a beautiful blue motting.

**Determination of water and impurities.**—Besides water, soap is often adulterated by gelatine, forming a soap sometimes called "bone soap," which is made by adding to the soap a solution of disintegrated bones, swines, skins, hoofs, sprats, and other cheap fish in strong caustic soda; also by dextrine, potato starch, pumice stone, silt, plaster, clay, salt, chalk, carbonate of soda, &c., and by fats of another or inferior kind than those from which they are represented to have been made. These impurities or superadded materials and their amount may be ascertained in the following manner:

**Estimation of the quantity of water:**—Take about 1,000 grains of the soap under examination, cut into small and thin slices, not only from the outside, which is always drier, but from the interior of the sample, so that the whole may represent a fair average; mix the mass well together, and of this weigh accurately 100 grains; place it in an oven heated to a temperature of 212° Fahr., until it is quite dry, weighing it occasionally until no loss or diminution of weight is observed, the difference between the original and the last weight, the loss, indicates, of course, the proportion of water. The loss of water in molled soap and in soft soap should not be more than 30 to 35 per cent.; in white or yellow soap from 36 to at most 30 per cent.

If the soap is sulphated, the amount of sulphate employed may be determined by taking 200 grains of the sample, dissolving it in a capsule with boiling water, adding to the boiling solution as much hydrochloric acid as is necessary to render the liquid strongly acid, and therefore to decompose the soap entirely, throwing the whole in a filter previously wetted with water, adding to the filtrate an excess of chloride of barium, washing thoroughly the
white precipitate so produced, igniting and weighing it; every grain of sulphate of barytes thus obtained represents 1.467 grain of crystallized sulphate of soda.

If the soap contains clay, chalk, silice, dextrine, fucalin, punice stone, ochre, plaster, salt, gelatine, &c, dissolve 100 grains of the suspected soap in alcohol, with the help of a gentle heat; the alcohol will dissolve the soap and leave all these impurities in an insoluble state. Good mottled soap should not leave more than 1 per cent. of insoluble matter, and white or yellow soap still less. All soap to which earthy or siliceous matter has been added is opaque instead of transparent at the edges, as is the case with all genuine or fitted and sulphated soap. The drier the soap, the more transparent it is.

Bone soap, or glue soap, is recognized by its unpleasant odor of glue and its dark color, its want of transparency at the edges; that made with the fat of the intestines of animals has a disgusting odor of fæces.

When uncombined silice has been added to soap, its presence may be readily detected by dissolving the suspected soap in alcohol, as before, when the silice will be left in an insoluble state; but if the silice is in the state of silicate of soda or of potash, it is necessary to proceed as follows:—dissolve a given weight of the suspected soap in boiling water, and decompose it by the gradual addition of moderately dilute hydrochloric acid, until the liquor is strongly acid; boil the whole for one or two minutes longer and allow it to cool in order that the fatty acids having separated and become hard, may be removed. Evaporate the acid liquor to perfect dryness, and the perfectly dry mass treated with boiling water will leave an insoluble residue which may be identified as silice by its grittiness, which is recognized by rubbing it in the capsule with a glass rod. This white residue should then be collected on a filter, washed, dried, ignited, and weighed.

The proportion of alkali (potash or soda) may be easily determined by an alkaliometrical assay as follows:

Take 100 grains of the soap under examination, and dissolve them in about 2,000 grains of boiling water; should any insoluble matter be left, decoct carefully the supernicent solution and test it with dilute sulphuric acid of the proper strength, exactly as described in the article on alkaliometry.

The proportion of alkali contained in soap may also be ascertained by incurring a given weight of soap in an iron or platinum spoon, crucible, or capsule, treating the residue with water, filtering and submitting the filtrate to an alkaliometrical assay. This method, however, cannot be resorted to when the soap contains sulphates of alkalies, because the ignition would convert such salts, or a portion thereof, into carbonates of alkali, which by saturating a portion of the test-sulphuric acid would give an inaccurate result.

The proportion of oil or fat in soap is ascertained by adding 100 grains of pure white wax free from water to the soap solution, after supersaturation with an acid, and heating the whole until the wax has become perfectly liquid, and has become perfectly incorporated with the oil or fat which has separated by the treatment with an acid. The whole is then allowed to cool, and the waxy cake obtained is removed, heated in a weighed crucible or capsule to a temperature of about 220° Fahr., in order to expel all the water,after which the whole is weighed; the increase above 100 grains (the original weight of the wax) indicates, of course, the quantity of grease, fat, or oil contained in the soap. This addition of wax is necessary only when the fatty matter of the soap is too liquid to solidify well in cooling.

Good soap ordinarily contains from 6 to 8 per cent. of soda; from 60 to 70 per cent. of fatty acids and resin, and from 50 to 85 per cent. of water.

The nature of the fat of which a given sample of soap has been made is more difficult to determine than to ascertain the aqueous solution of the mass under examination with an acid, collecting the fatty acids which then float on the surface, and observing their point of fusion, the operator at any rate will be thus enabled to ascertain whether the soap under examination is identical with the sample from which it may have been purchased, and whether it was made from tallow, or from oil, &c.

When the fatty acids which have been isolated and collected by decomposing the soap with an acid, as already described, are heated in a small capsule the odor evolved is often characteristic, or at least generally gives a clue to the nature of the fats or oils from which the soap has been made. This odor is often sufficiently perceptible at the moment when the aqueous solution of the soap is decomposed by the acid poured in. Cocoa-nut oil can always be detected when in proportions at all available to the soap-maker by tasting the soap, that is to say, by leaving the tongue in contact with the soap for a few moments, when a peculiar, very disagreeable and bitter flavor will become more or less perceptible.

Properly made soap should dissolve completely in pure water; if a film or oily matter is seen to float on the surface, it is a proof that all the fat is not saponified. Another test is that the fatty or oily acid separated by decomposing the aqueous solution of the soap by hydrochloric acid, should be entirely soluble in alcohol.

Bone soap, as we said, are combinations of fats or oils with potash, or rather are solutions of a potash soap, in a lye of potash, and they therefore always contain a great excess of alkali, and a more or less considerable proportion of water; they contain also a certain
quantity of chlorides, of sulphates, and all the glycerine which the saponifying process has set free. Soft soap in this country is generally used for fulling, and for cleansing and scouring woollen stuffs. In Belgium, Holland, and Germany it is used also for washing linen, which thereby acquires an almost intolerable odor of fish oil, which no amount of perfume can mask, fish oil being generally employed in the manufacture of that description of soap. The most esteemed soft soap, however, is that made from hempseed oil, which imparts to the soap a greenish color, but this much-prized color is generally or very often artificially given to the soap made of other oil, which soap has a yellow color, by means of a little judicious finely pulverized and previously boiled for some time in water. For further particulars on the manufacture of soap, see vol. ii.

**SODA, CARBONATE OF (Kohlensauers natron, Germ.) Manufacture.**—The manufacture divides itself into three branches:—1. The conversion of sea salt, or chloride of sodium, into sulphate of soda. 2. The decomposition of this sulphate into crude soda, called *black balls* by the workmen. 3. The purification of these balls, either into a dry white soda ash or into crystals.

**Preparation of Sulphate of Soda.**—The decomposition of the common salt (chloride of sodium) by sulphuric acid is effected in furnaces, of which fig. 608 is a drawing, taken from Dr. Miller's *Elements of Chemistry*. A, the smaller of the two compartments which compose the furnace, is of cast iron; into this (the decomposer) from five to six hundred weight of common salt are introduced, and an equal weight of sulphuric acid, of specific gravity 1·9, is gradually mixed with it; a gentle heat being applied to the outside, enormous volumes of hydrochloric acid gas are disengaged, and pass off by the flue *d* to the condensing towers *e* and *f*; these towers are filled with fragments of broken coke, or stone, over which a continuous stream of water is caused to trickle slowly from *h* to *h*. A steady current of air is drawn through the furnace and condensing towers, by connecting the first tower with the second, as represented at *g*, and the second tower with the main chimney, *k*, of the works. In the first bed of the furnace, about half of the common salt is decomposed, leaving a mixture of bisulphate of soda and common salt; which requires a greater heat for the expulsion of this latter portion of hydrochloric acid; for this purpose it is pushed through a door into the *roaster*, or second division, *b*, of the furnace.

The reaction in the first bed of the furnace is represented as follows:

\[
2\text{NaCl} + 2\text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{HCl} + \text{NaCl}
\]


By the higher temperature obtained in this second part of the furnace, the bisulphate or soda reacts on the undecomposed chloride of sodium, yielding neutral sulphate of soda and a fresh quantity of hydrochloric acid.

\[
\text{Na}_2\text{SO}_4 + \text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{SO}_4
\]


The hydrochloric acid gas, as it is liberated from *a*, passes off through the flue, *d*, and is carried on to the condensing towers. Heat is applied to the outside of the roaster, *n*; the smoke, *c*, circulating in separate flues around the chamber, in the direction indicated by the arrows, but never coming into contact with the salt cake in *b*.

By the kindness of J. L. Bell, Esq., of Newcastle-upon-Tyne, we are enabled to give the
SODA, CARBONATE OF.

The process used at present in that district. It differs but little from that above described, with the exception that in the decomposition of the mixture of bisulphate of soda and common salt, in the second portion of the furnace, the smoke and products of combustion from the fire are allowed to come in contact with the materials, and the hydrochloric acid which is then given off is carried to condensing towers filled with bricks over which water is continu-

ally slowly running, and the dilute hydrochloric acid thus obtained is used for the liberation of carbolic acid in the manufacture of bicarbonate of soda. The first part of the furnace is a circular metal pan, and the hydrochloric acid from this being unmixed with smoke, &c., is condensed apart from the other.

The next step in the manufacture is the decomposition of the sulphate of soda into sulphide of sodium, and its subsequent con-

version into carbonate of soda. This is 

effectuated in the following manner:—The dry sulphate of soda, obtained by the process above described, is mixed with small coal and chalk, or limestone, in about the follow-

ing proportions: sulphate of soda 3 parts, chalk 3½ parts, and coal 2 parts. It is necessary that these materials should be first separately ground, and sifted into a tolerably fine powder, and then carefully mixed, as a great deal depends on the attention to these points. The mixture is then subjected to heat in a reverberatory fur-

nace, figs. 609, 610, 611.

In the section fig. 610, there are two hearths in one furnace, the one elevated above the level of the other by the thick-

ness of a brick, or about three inches. A is the preparatory shelf, where the mixture to be decomposed is first laid in order to be thoroughly heated, so that, when transferred to the lower or decomposing hearth B, it may not essentially chill it, and throw back the operation. C is the fire bridge, and D is the grate. In the horizontal section, or ground plan, fig. 611, we see an opening in the front corresponding to each hearth. This is a door, as shown in the side view or elevation of the furnace, fig. 609; and each door is shut by an iron square frame filled with a fire tile or bricks, and suspended by a chain over a pulley fixed in any convenient place. The workman, on pushing up the door lightly, makes it rise, because there is a coun-

ter weight at the other end of each chain, which balances the weight of the frame and bricks.

In the ground plan, only one smoke flue is shown; and this construction is preferred by many manufacturers; but others choose to have two flues, one from each shoulder, as at a, b; which two flues afterward unite in one vertical chimney, from 25 to 40 feet high; because the draught of a soda furnace must be very sharp. Having sufficiently explained the construction of this improved furnace, we shall now proceed to describe the mode of making soda with it.

The quantity of this mixture required for a charge depends, of course, on the size of the furnace. This charge must be shovelled in upon the hearth A, or shelf of preparation, (fig. 610); and whenever it has become hot, (the furnace having been previously brought to bright ignition,) it is to be transferred to the decomposing hearth or laboratory B, by an iron tool, shaped exactly like an oar, called the spreader. This tool has the flattened part from 2 to 3 feet long, and the round part, for laying hold of and working by, from 6 to 7 feet long. Two other tools are used; one a rake, bent down with a garden hoe at the end; and another, a small shovel, consisting of a long iron rod terminated like a piece of iron plate, about 6 inches long, 4 broad, sharpened and tipped with steel, for cleaning the bottom of the hearth from adhering cakes or crusts. Whenever the charge is shoved by the sliding motion of the oar down upon the working hearth, a fresh charge should be thrown into the preparation shelf, and evenly spread over the surface.

The hot and partially carbonized charge being also evenly spread upon the hearth n, is to be left untouched for about ten minutes, during which time it becomes ignited, and begins to fuse upon the surface. A view may be taken of it through a peep-hole in the door, which should be shut immediately, in order to prevent the reduction of the temperature. When the mass is seen to be in a state of incipient fusion, the workman takes the oar and turns it over breadth by breadth in regular layers, till he has reversed the position of the whole
mass, placing on the surface the particles which were formerly in contact with the hearth. Having done this he immediately shuts the door, and lets the whole get another decomposing hour. After five or six minutes, jets of flame begin to issue from various parts of the paste-consistenced mass. Now is the time to incorporate the materials together, turning and spreading by the oar, gathering them together by the rake, and then distributing them on the reverse part of the hearth; that is, the oar should transfer to the part next the firebridge the portion of the mass lying next the shelf, and vice versa. The dexterous management of this transposition characterizes a good soda furnace. A little practice and instruction will render this operation easy to a robust, clever workman. After this transposition, incorporation, and spreading, the door may be shut again for a few minutes, to raise the heat for the finishing off. Lastly, the rake must be dexterously employed to mix, shift, spread, and incorporate. The jets called candles, are very numerous, and bright at first; and whenever they begin to fade, the mass must be raked out into cast iron moulds, placed under the door of the laboratory to receive the ignited paste.

One batch being thus worked off, the other, which has lain undisturbed on the shelf, is to be shovelled down from A to B, and spread equally upon it, in order to be treated as above described. A third batch is then to be placed on the shelf.

The product thus obtained is called "black balls," which of course vary in their composition. The following is the composition, according to Richardson, of the Newcastle "black balls" from the balling furnaces:

Carbonate of soda 98.9, hydrate of soda 25.64, sulphide of calcium 35.57, carbonate of time 15.67, sulphate of soda 5.64, chloride of sodium 0.60, sulphide of iron 1.22, silicate of magnesia 0.88, carbon 4.28, sand 0.44, and water 2.17.

The principal changes which take place in this process may be represented by the following equations:

\[ \text{NaSO}_4 + 4\text{C} \rightarrow \text{NaS} + 4\text{CO} \]

then:

\[ \text{NaS} + \text{CaCO}_3 \rightarrow \text{NaCO}_3 + \text{CaS} \]

In the first place, the sulphate of soda is deoxidized by the coal, with the formation of sulphide of sodium and carbonic oxide, which latter takes fire and forms the candles above mentioned; in the next place, the sulphide of sodium and carbonate of lime (chalk) decompose each other, forming carbonate of soda and sulphide of calcium; and from the fact of some of the chalk being converted into caustic lime by the heat of the furnace, there is also formed by it some caustic soda; the sulphide of calcium itself is only sparingly soluble in water, but is rendered still less so by the excess of lime which is present, forming with it an oxysulphide, which is much less soluble than the sulphide of calcium alone.

This black ball, or ball alkali, is then treated with warm water to extract the soluble matters. This is effected in the districts of Newcastle-on-Tyne in vessels 8 or 10 feet square and 5 or 6 feet deep, furnished with false bottoms; the first waters are strong enough for boiling down, for getting yellow salt, as it is termed; the after washings, which are weaker, are used for fresh quantities of "ball alkali." Care must be taken not to use the water too hot, as the oxysulphide of calcium would be decomposed, and the liquor thus take up much sulphide of calcium.

An apparatus used in some places for lixiviating the black ball is shown in the accompanying drawing, fig. 612, taken from Dr. Miller's "Elements of Chemistry." It is object to extract the largest quantity of soluble matter with the smallest quantity of water. The black ball is placed in perforated sheet-iron vessels, H H, which can be raised or lowered into outer lixiviating vessels, also made of iron, by means of the cords and pulleys I, I. When a charge is received from the furnace, it is introduced into the lowest vessel G, where it is submitted to the dissolving action of a liquid already highly charged with alkali from digestion upon the black ash contained in the tanks above it; after a certain time this charge is raised by the rope from G into the tank F, where it is submitted to a weaker liquid, and so on, successively. The alkali at each stage becomes more completely exhausted, and the residue is successively submitted to the action of weaker lye, till at length, in A, it is acted on by water only, supplied from the cistern L. When fresh water is admitted from M, to the top of the vessel A, as it is specifically lighter than the saline solution, it lies upon its surface, and gradually displaces the solution from A through the beat tube, whilst the water takes its place; the liquid thus displaced from it, acts in like manner upon that contained in B; and this displacement proceeds simultaneously through each successive tier of the arrangement, until the concentrated lye runs off from A, and is transferred to the evaporating pans. The residue which remains after this treatment contains nearly all the sulphur present in the ball alkali, in the form of oxysulphide of calcium, together with the other insoluble portions.
and is of no value; it accumulates to an immense extent in large soda works, and is thus a source of annoyance. Many trials have been made to obtain the sulphur contained in it, and to use it for the reproduction of sulphuric acid, but without much success hitherto.

The solution obtained by thus lixiviating the ball soda, contains principally carbonate of soda and hydrate of soda, as well as some sulphide and chloride of sodium, and a little sulphate of soda. It is allowed to settle; then the clear liquor is drawn off into evaporating vessels. These may be of two kinds. The surface-evaporating furnace, shown in fig. 613, is a very admirable invention for economizing vessels, time, and fuel. The grate, A, and fire-place, are separated from the evaporating laboratory, B, by a double fire bridge, C, D, having an interstitial space in the middle, to arrest the communication of a melting or igniting heat toward the lead-lined cistern, E. This cistern may be 8, 10, or 20 feet long, according to the magnitude of the soda-work, and 4 feet or more wide. Its depth should be about 4 feet. It consists of sheet lead, of about 6 pounds weight to the square foot, and it is lined with one layer of bricks, set in Roman or hydraulic cement, both along the bottom and up the sides and ends. The lead comes up to the top of C, and the liquor, or lye, may be filled in to nearly that height. Things being thus arranged, a fire is kindled upon the grate, A; the flame and hot air sweep along the surface of the liquor, raise its temperature there rapidly to the boiling point, and carry off the watery parts in vapor up the chimney, E, which should be 15 or 20 feet high, to command a good draught. But, indeed, it will be most economical to build one high, capacious chimney stalk, as is now done at Glasgow, Manchester, and Newcastle, and to lead the flux of the several furnaces above described into it. In this evaporating furnace the heavier and stronger lye goes to the bottom, as well as the impurities, where they remain undisturbed. Whenever the liquor has attained to the density of 1.3, or thereby, it is pumped up into evaporating cast-iron pans, of a flattened, somewhat hemispherical shape, and evaporated to dryness while being diligently stirred with an iron rake and iron scraper.

This alkali gets partially carbonated by the above surface-evaporating furnace, and is an excellent article.

When pure carbonate is wanted, that dry mass must be mixed with its own bulk of ground coal, sawdust, or charcoal, and thrown into a reverberatory furnace. Here it must be exposed to a heat not exceeding 650° or 700° F.; that is, a little above the melting heat of lead; the only object being to volatilize the sulphur present in the mass, and carbonate the alkali. Now, it has been found, that if the heat be raised to distinct redness, the sulphur will not go off, but will continue in intimate union with the soda. This process is called caking, and the furnace is called a caker furnace. It may be 6 or 8 feet long, and 4 or 5 feet broad in the hearth, and requires only one door in its side, with a hanging iron frame filled with a fire-tile or bricks as above described.
SODA, CARBONATE OF.

This carbonating process may be performed upon several cwts. of the impure soda mixed with sawdust, at a time. It takes three or four hours to finish the desulphuration; and it must be carefully turned over by the oar and the rake, in order to burn the coal into carbonic acid, and to present the carbonic acid to the particles of caustic soda diffused through the mud, so that it may combine with them.

When the blue flames cease, and the saline matters become white, in the midst of the oily matter, the batch may be considered as completed. It is raked out, and, when cooled, lixiviated in great iron cisterns with false bottoms, covered with mats. The watery solution being drawn off clear by a plug-hole, is evaporated either to dryness, in hemispherical cast-iron pans, as already described, or only to such a strength that it shows a pellicle upon its surface, when it may be run off into crystallizing cisterns of cast iron, or lead-lined wooden cisterns. The above dry carbonate is the best article for the glass manufacture.

Instead of this last process of roasting with sawdust, Gosse decomposes the sulphide of sodium present in the lye obtained from the ball soda, by means of the hydrated oxide of some metal, as of lead, thus forming sulphide of lead and hydrate of soda; this is then converted into carbonate by passing a stream of carbonic acid through it. The precipitated sulphide of lead is decomposed by hydrochloric acid, thus generating sulphurated hydrogen, which is burnt and converted into sulphuric acid; the lead is then converted again into hydrated oxide by means of lime. This process saves the trouble, time, and fuel used in evaporating to dryness twice, as in the ordinary process.

Various attempts have been made to obtain processes which shall supersede the process above described, of manufacturing carbonate of soda from common salt, but none appear to have been successful to any great extent. We shall here mention some of them.

1. Sulphate of iron, being a cheap article, has been heated with common salt instead of using sulphuric acid; sulphate of soda is formed, and the chloride of iron, being volatile, passes away. The latter part of the process was of course similar to that above described.

2. By roasting iron or copper pyrites directly with chloride of sodium, sulphate of soda has been obtained, and it has been found possible by this means also to extract the metal from ores of copper or tin with advantage, which are otherwise too poor to work. Mr. Tilghman effects the decomposition of chloride of sodium by steam at a high temperature, in the presence of alumina. Precipitated alumina is made up into balls with chloride of sodium, and exposed to a current of steam in a reverberatory furnace strongly heated. Hydrochloric acid is expelled and the alumina unites with the soda.

\[
\text{NaCl} + \text{Al} \text{O}_3 + \text{HO} = \text{NaO}_3\text{Al} \text{O}_3 + \text{HCl}
\]


When cold, this compound of alumina and soda is decomposed by a current of carbonic acid, and the carbonate of soda is dissolved, and thus separated from the alumina, which may be again used. Another process is that patented by MM. Schloesing and Rolhand, which is as follows: — They dissolve the chloride of sodium in water, and then pass ammonia into it, and after ward carbonic acid; bicarbonate of ammonia is first produced, and then double decomposition takes place; chloride of ammonium is formed, and the more sparingly soluble bicarbonate of soda is precipitated in crystaline grains; it is then separated from the liquid and pressed, to free it as much as possible from the chloride.

\[
\text{NaCl} + \text{NH}_3\text{CO}_3\text{HCO}_3 = \text{NaCO}_3\text{HCO}_3 + \text{NH}_3\text{HCO}_3
\]


This bicarbonate of soda is converted into the monobarbonate by heat, and the carbonic acid thus evolved is used again; the solution, from which the bicarbonate has separated, is boiled to drive off any ammonia that it may contain, as carbonate of ammonia, which is collected; the solution is then boiled with lime, which liberates the ammonia from the chloride of ammonium, and thus little loss is sustained, the same ammonia serving continually, within certain limits, because, of course, some ammonia escapes and is unavoidable lost.

There are three carbonates of soda commonly known, viz., mono carbonate, sesquicarbonate, and bicarbonate.

Monocarbonate. \(\text{NaCO}_3 \cdot 10\text{HO}\). This is the salt which is obtained in the ordinary soda manufacture. In the crystalline state, it generally contains ten equivalents of water of crystallization, sixty-three per cent., but has been obtained with only eight, five, and even one equivalent of water. It effloresces in a dry atmosphere, at the same time absorbing carbonic acid. It is very soluble in water, requiring only twice its weight of water at 60° for solution, and even melts in its own water of crystallization when heated, and eventually by increase of temperature becomes anhydrous. It is generally found in commerce in large crystals, which belong to the oblique prismatic system. It is strongly alkaline, and acts on the skin, dissolving the outside cuticle. It is largely used in the manufacture of soap, glass, &c., and is generally too well known to require much description.

The soda trade made great progress in 1839, as compared with the two preceding years. In 1837, 1,538,988 cwts. were exported, of the value of £760,741; and in 1838,
SODA, NITRATE OF.

1,618,289 cwt., of the value of £818,727; whilst last year the quantity was 2,027,609, cwt., and the value £1,024,283.

Sesquicarbonate. 2NaCO₃HCO₃. This salt is frequently found native, and is described under SODA, vol. ii., (which see.)

Bicarbonate. NaCO₃HCO₃. This salt is found in some mineral waters, as those of Carlsbad and Seltzer; and is obtained from the waters of Vichy in large quantities.

It is prepared by saturating the monocarbonate with carbonic acid, for which purpose several methods are employed.

1. By passing carbonic acid into a solution of the monocarbonate.—A cold saturated solution of the monocarbonate of soda is made, and carbonic acid, obtained by the action of hydrochloric acid on marble or chalk, is passed into it; the bicarbonate forms and precipitates to a great extent, and is then collected, pressed to remove as much of the adhering liquid as possible. A fresh portion of the monocarbonate is dissolved in the mother liquor, and the passage of carbonic acid through it repeated. By this method a pure bicarbonate is obtained, but the process is costly.

2. By exposing solid monocarbonate of soda to an atmosphere of carbonic acid gas.—This is known as Smith's process. The crystals of the monocarbonate are placed on shelves, slightly inclined to allow the water to run off, in a large box, containing a perforated false bottom; carbonic acid is passed into this box under pressure, which latter is scarcely necessary, since the monocarbonate so rapidly absorbs the carbonic acid. When the gas ceases to be absorbed, the salt is taken out and dried by a gentle heat.

The crystals are found to have lost their water of crystallization, and to have become opaque and porous, and a bicarbonate, still, however, retaining their original shape. These are ground between stones like flour, care being taken to avoid the evolution of much heat.

This is the most economical process, but does not yield a perfectly pure product, yet, nevertheless, quite pure enough for ordinary purposes, the impurities contained in it being a little chloride of sodium and sulphate of soda, found in the original monocarbonate from which it was made, and even these to a great extent dissolved and carried off by the water of crystallization as it escapes.

3. Its formation by the action of bicarbonate of ammonia has already described.

Bicarbonate of soda crystallizes in rectangular four-sided prisms, which require about ten parts of cold water to dissolve them, and if the solution be boiled, it loses carbonic acid, becoming first sesquicarbonate, and ultimately monocarbonate. As usually met with in commerce, this salt is a white powder. Its taste is slightly alkaline. It is largely used in medicine, for making seidlitz powders, &c.; but the salt generally found in the shops is only a sesquicarbonate, or a mixture of bicarbonate and sesquicarbonate.—H. K. B.

SODA, NITRATE OF. (NaO₃NO₃.) Syn. cubic nitre; Chile, saltpetre. (Nitrato de sonde, Fr.; Würzelflaschen, Ger.) This important salt is found native in immense quantities in Chili and Peru. It is, in some parts, found in beds of several feet in thickness. As found in nature it is tolerably pure, the principal impurities being chlorine, sulphuric acid, and lime.

It is evident that nitrate of soda can be formed artificially by saturating nitric acid with soda or its carbonate, and evaporating the solution until the salt crystallizes.

In analyzing a sample of the salt, it should be dissolved in boiling distilled water; any insoluble matters are to be removed by the filter, and, after being washed and dried, may be weighed. To the clear filtrate acidulated with pure nitric acid, nitrate of silver is to be added; the precipitate of chloride of silver, when weighed with proper precautions, will enable the amount of chloride of sodium to be calculated. For this purpose we say: as one equivalent of chloride of silver is to one equivalent of chloride of sodium, so is the quantity of chloride of silver obtained to the quantity of chloride of sodium in the specimen taken. In another portion of the salt, the solution being prepared as before, the sulphuric acid may be determined by precipitation with chloride of barium; and, in a third, the lime and magnesia are to be determined by precipitation, the first with oxalate of ammonia, and the latter in the filtrate from the oxalate of lime, by means of phosphate of soda and ammonia. The water may be determined by drying a known weight of the salt in the water bath until it ceases to diminish in weight. A good sample of nitrate of soda should not contain more than two per cent, of chloride of sodium.

Solubility of Nitrate of Soda in Water.

One part of the salt dissolves in—

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1°58</td>
<td>32°</td>
</tr>
<tr>
<td>1°25</td>
<td>66°</td>
</tr>
<tr>
<td>1°36</td>
<td>88°</td>
</tr>
<tr>
<td>0°77</td>
<td>116°6</td>
</tr>
<tr>
<td>0°46</td>
<td>24°52</td>
</tr>
</tbody>
</table>

The above table is not perfectly satisfactory, and the solubility of nitrate of soda in water at different temperatures requires reinvestigation.
SOLDERS.

Nitrate of soda is not applicable for the preparation of gunpowder or fireworks, partly in consequence of its tendency to attract moisture from the air, and partly owing to the fact that mixtures made in imitation of gunpowder, but having nitrate of soda in place of nitrate of potash, explode far less powerfully than gunpowder itself.

Nitrate of soda is extensively and economically employed as a source of nitric acid. It is also used for the purpose of being converted by double decomposition with chloride of potassium into nitrate of potash. It is employed in great quantities as a manure.

The term cubic nitre applied to this salt is incorrect; the crystals, it is true, appear cubic at a rough glance, but they are in fact, rhombobolohra, of which the angles are not very far removed from those of a cube. - J. G. W.

SODIUM (Na). This metal was discovered by Sir H. Davy, almost immediately after potassium, and by the same means, viz., by exposing a piece of moistened hydrate of soda to the action of a powerful voltaic battery, the alkali being placed between a pair of platinum plates connected with the battery.

By this process only very small quantities could be obtained, and processes have since been devised which provide it in almost any quantity, and since the demand for sodium in the manufacture of aluminium by Wöhler's process, principally by the exertions of M. St. Clair Deville, the cost of it has been considerably diminished. The process now adopted is the same as that for obtaining potassium; an intimate mixture of carbonate of soda and charcoal is made by igniting in a covered crucible a salt of soda containing an organic acid, as the acetate of soda, &c., or by melting ordinary carbonate of soda in its water of crystallization and mixing with it, while liquid, finely divided charcoal, and evaporating to dryness; this mixture is mixed with some lumps of charcoal and placed in a retort, which is generally made of malleable iron; but, owing to the difficulty of getting these sufficiently large, earthware or fireclay retorts have been used with success, and sometimes these are lined with or contain a tough of malleable iron. These retorts are so placed in a furnace that they are uniformly kept at a heat approaching to whiteness.

Mr. Beatson (Pharmaceutical Journal, vol. x. p. 226) made an improvement in the process by which it can be carried on continuously for a week or fortnight. If the proportion of charcoal and soda be well regulated, the retort becomes nearly empty at the end of the process. In Mr. Beatson's process, as soon as one charge is worked off the receiver is removed, and a fresh charge is introduced through the same tube as serves to convey the sodium to the receiver, by means of a semicircular scoop, so that the retort is kept at a constant temperature, and hence little loss of time. The receiver contains rock-naphtha, and is surrounded by cold water. The manufacture of sodium, when properly conducted, is much easier and more certain than that of potassium; one advantage is, that the sodium does not unite with carbolic oxide to form the explosive compound, and the conducting tube is not so likely to be choked. The sodium which comes over is, however, mixed with some impurities, croconates, &c.; and in order to separate the metal from these, Mr. Beatson melted the sodium under mineral naphtha, in a cylinder, into which is fitted a piston, worked by a screw or hydraulic press, and when this is forced down the metal forms in a mass above it, while the impurities remain at the bottom of the cylinder.

The principal reaction which takes place in the retort, is the reduction of the soda by the charcoal, which is thus converted into carbolic oxide, which escapes through an aperture in the receiver made on purpose.

\[ \text{NaO} + \text{C} = \text{Na} + \text{CO} \]

Soda, Charcoal, Sodium, Carbolic oxide.

Sodium is a silver-white metal, very much resembling potassium in every respect; it is so soft at ordinary temperatures that it may be easily cut with a knife or pressed between the finger and thumb; it melts at 194° F., and oxidizes rapidly in the air, though not so rapidly as potassium. Its sp. gr. is 0.972. When placed upon the surface of cold water it decomposes it with violence, but does not ignite the hydrogen which is liberated, unless the motion of the sodium be restrained, when the cooling effect is much less. When a few drops of water are added to sodium the hydrogen liberated immediately inflames, and such is also the case if it be put on hot water; when burning it produces a yellow flame, and yields a solution of soda. The equivalent of sodium is 23.

When sodium is burnt in oxygen gas or in air, two different oxides are produced, viz. the protoxide, (NaO) and another whose composition is uncertain, perhaps binoxide (NaO₂) or teroxide, (NaO₃). These oxides also very much resemble the corresponding oxide of potassium. The principal use of sodium is, as before stated, in the manufacture of aluminium, which is now carried on up to a considerable extent. See ALUMINUM.—H. K. B. to a considerable extent. See ALUMINUM.—H. K. B.

SOLDERS. Alloys which are employed for the purpose of joining together metals are so called. They are of various kinds, being generally distinguished into hard and soft. Upon the authority of Holtzappel, the following receipts for solder are given, and these have been adopted, because, after a long and particular inquiry in the workshops, we learn that these are regarded as very superior to any others recommended.

Vol. III.—63
Speculum Metal.

Pentesters' Solder. (a) 2 Bismuth, 4 lead, 3 tin. (b) 1 Bismuth, 1 lead, 2 tin.
Soft Solderer. Equal parts of copper and zinc.
Coarse Plumbers' Solder. (a) 1 tin, 3 lead, melts at about 500 F. (b) 2 tin, 1 lead, melts at about 360 F.
Solder Solder. 12 oz. of zinc to 16 oz. of copper.

(For brass work the metals are generally mixed in equal proportions as above. For copper and iron the last given are usually employed.)

The following Table of solders has been constructed by the late Mr. Holtzappfel, from a Table of a much more extended character, published by Mons. H. Gaulthier de Clauvry.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Melting Point (°F)</th>
<th>Fluxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 Tin 25 Lead</td>
<td>A. Borax.</td>
</tr>
<tr>
<td>2</td>
<td>1 &quot; 10 &quot;</td>
<td>B. Oxal ammonium.</td>
</tr>
<tr>
<td>3</td>
<td>1 &quot; 5 &quot;</td>
<td>C. Chloride of zinc.</td>
</tr>
<tr>
<td>4</td>
<td>1 &quot; 3 &quot;</td>
<td>D. Common resin.</td>
</tr>
<tr>
<td>5</td>
<td>1 &quot; 2 &quot;</td>
<td>E. Venice turpentine.</td>
</tr>
<tr>
<td>6</td>
<td>1 &quot; 1 &quot;</td>
<td>F. Tallow.</td>
</tr>
<tr>
<td>7</td>
<td>1 &quot; 1 &quot;</td>
<td>G. Gallipoli oil.</td>
</tr>
<tr>
<td>8</td>
<td>2 &quot; 1 &quot;</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3 &quot; 1 &quot;</td>
<td>a. Naked fire.</td>
</tr>
<tr>
<td>10</td>
<td>4 &quot; 1 &quot;</td>
<td>b. Hollow furnace or muffle.</td>
</tr>
<tr>
<td>11</td>
<td>5 &quot; 1 &quot;</td>
<td>c. Immersion in melted solder.</td>
</tr>
<tr>
<td>12</td>
<td>6 &quot; 1 &quot;</td>
<td>d. Melted solder poured on.</td>
</tr>
<tr>
<td>13</td>
<td>4 Lead 4 Tin 1 Bismuth</td>
<td>e. Heated iron not tinned.</td>
</tr>
<tr>
<td>14</td>
<td>3 &quot; 3 &quot; 1 &quot;</td>
<td>f. Heated copper tool tinned.</td>
</tr>
<tr>
<td>15</td>
<td>2 &quot; 2 &quot; 1 &quot;</td>
<td>g. Biowpipe flame.</td>
</tr>
<tr>
<td>16</td>
<td>1 &quot; 1 &quot; 1 &quot;</td>
<td>h. Flame alone, generally alcohol.</td>
</tr>
<tr>
<td>17</td>
<td>2 &quot; 1 &quot; 1 &quot;</td>
<td>i. Stream of heated air.</td>
</tr>
<tr>
<td>18</td>
<td>3 &quot; 5 &quot; 3 &quot;</td>
<td></td>
</tr>
</tbody>
</table>

Modes of Applying Heat.

SPEClUM METAL. The metal employed in the mirrors of reflecting telescopes. The Earl of Rosse, who has been eminently successful in the production and publishing of large specula, says, in his paper published in the Transactions of the Royal Society, "Tin and copper, the materials employed by Newton in the first reflecting telescope, are preferable to any other with which I am acquainted, the best proportions being 4 atoms of copper to 1 of tin, (Turner's numbers;) in fact, 126+4 parts of copper to 58·9 of tin."

Mr. Rosse remarks that when the alloy for speculum metal is perfect, it should be white, glassy, and flaky. Copper in excess imparts a reddish tinge, and when tin is in excess, the fracture is granulated and less white. Mr. Ross pours the melted tin into the copper, when it is at the lowest temperature at which a mixture by stirring can be effected; then he pours the metal into an ingot, and, to complete the combination, remelts it in the most gradual manner, by putting the metal into the furnace almost as soon as the fire is lighted. Trial is made of a small portion taken from the pot immediately prior to pouring.

SPIRIT OF SALTS. Hydrochloric or muriatic acid.

SPIRITS OF WINE. Alcohol, (which see.)

SPONGE. (Eponge, Fr.; Sekanum, Germ.) For a long time it was a disputed point whether the sponge of commerce belonged to the animal or the vegetable kingdom. Of late years the evidence has appeared to be conclusive as to its animal nature.

The sponge consists of a soft gelatinous mass, mostly supported by an internal skeleton composed of reticulately anastomosing horny fibres, in or among which are usually imbedded siliceous or calcareous spicula. Sponges are mostly marine—two or three species only being found in fresh water. They are fixed by a kind of root, by which they hold firmly any surface upon which they once fix themselves. Sponges may be propagated by division, but more usually by gemmules, which detach themselves from the parent body, and float about until they find a fitting resting-place, where they fix themselves and grow. The sponges of commerce are obtained from the Mediterranean—Smyrna being the principal market. They are collected by divers, many of whom have been trained to the work from their infancy. Sponges are treated with muriatic (hydrochloric) acid to remove the lime.

SPRUE BEER is prepared as follows:—Essence of spruce, half a pint; pimento and ginger bruised, of each 4 ounces; hops, from 4 to 5 ounces; water, 5 gallons. Boil for ten minutes, then strain and add 11 gallons of warm water, a pint of yeast, and 6 pints of molasses. Mix, and allow the mixture to ferment for twenty hours.

SPRUE, ESSENCE OF, is prepared by boiling the young tops of the Abies nigra, or black spruce, in water, and concentrating the decoction by evaporation.

* No. 5 is the Plumbers' sealed solder, which is assayed and then stamped by an officer of the Plumbers' Company.
STANXATE OF SODA. The process of Mr. James Young for the preparation of stan-
nate of soda, presents a very beautiful application of science. Instead of reducing metallic
in from the ore, and oxidating the metal again to form the stannic acid at the expense of
nitric acid, Mr. Young takes the native peroxide of tin itself, and fuses it with soda. The
iron and other foreign metals present in the ore are insoluble in water, and a pure stannate of soda is obtained at once. It is crystal-
lized by evaporation, and obtained in efflorescent crystals containing nine equivalents of water.

STEAM is a chemical compound of oxygen and hydrogen, in the proportion of 8 parts
by weight of oxygen, to 1 of hydrogen. Its composition by volume is such, that the quan-
tity of steam which, if it were a perfect gas, would occupy 1 cubic foot at a given pressure
and temperature, contains as much oxygen as would, if uncombined, occupy half a cubic
foot, and as much hydrogen as would, if uncombined, occupy 1 cubic foot, at the same pres-
sure and temperature; so that steam, if it were a perfect gas, would occupy two-thirds the
space which its constituents occupy when uncombined. Hence is deduced the following
composition of the weight 1 cubic foot of steam would have at the temperature of 32
Fahr., and pressure of one atmosphere, (or 14.7 lbs. on the square inch,) if steam were a per-
fector gas, and if it could exist at the pressure and temperature stated.

Data from the Experiments of Regnault.

| Weight of a cubic foot of steam in the ideal state of perfect gas, at one atmosphere and 32° | Lbs.          |
| 1 cubic foot of hydrogen                         |              |
| 1 cubic foot of steam in the ideal state of perfect gas, at one atmosphere and 32° | 0.044628     |
| If steam were a perfect gas, the weight of a cubic foot could be calculated for any given pressure and temperature by the following formulæ:— |
| Weight of a cubic foot = \(0.05022 \times \frac{493.6}{\text{Temp.} + 4.91.2} \) x    |
| For example, at one atmosphere of pressure, and 212°, the weight of a cubic foot of steam would be:— |
| \(0.05022 \times \frac{493.6}{673.9} = 0.03879 \text{ lb.} \) |

But steam is known not to be a perfect gas; and its actual density is greater than that
which is given by the preceding formulæ, though to what extent is not yet known by direct
experiment. The most probable method of indirectly determining the density of steam, is
by computation from the latent heat of evaporation, from which it appears that at one at-
mosphere and 212°, the weight of a cubic foot of steam is probably 0.0379 lb. The grea-
est pressure under which steam can exist at a given temperature, is called the pressure of
saturation for steam of a given temperature. The temperature is called the boiling point
of water under the given temperature. The pressure of saturation is the only pressure at
which steam and liquid water can exist together in the same vessel at a given temperature.

It becomes necessary to understand correctly the method of determining fixed tempera-
tures by certain phenomena taking place at them. Thus ice begins to melt at a point,
which we call the Freezing Point, marked 32° upon the scale devised by Fahrenheit, (see
Thermometer, Vol. ii;) and we determine the Boiling Point of water to be 212° on the same
scale, under the average atmospheric pressure of 14.7 lbs. on the square inch; 2116.4 lbs. on
the square foot; 29.992 inches of the column of mercury. At this latter point water ceses
to be liquid, and becomes vaporiform. From 32° to 212°, all the heat which has been poured
into the water, has effected no change of physical condition, but the higher temperature
being reached, a new condition is established, and steam is produced—this steam then be-
ing to act according to certain fixed laws.

A cubic inch of water, evaporated under the ordinary atmospheric pressure, is converted
into a cubic foot of steam.

A cubic inch of water, evaporated under the atmospheric pressure, gives a mechanical
force equal to what would raise a ton weight 1 foot high.

These are the effects produced at 212° under the above-named pressure.

Careful experiments have determined, within very small limits of error, the following
facts:—Steam under pressure of 35 lbs. per square inch, and at the temperature of 261°,
exerts a force equal to a ton weight raised one foot; under the pressure of 15 lbs. and at
the temperature of 212°, it is 2.086 lbs., or about seven per cent. less; and under 70 lbs.
and at 306° it is 2.382 lbs., or nearly six and a half per cent. more than a ton raised a foot.

It is sufficient for all practical purposes to assume that each cubic inch evaporated, whatever
be the pressure, develops a gross mechanical effort equivalent to a ton weight raised 1 foot.

As a given power is produced by a given rate of evaporation, to determine this the fol-
lowing rules are applicable:—
STEAM.

To produce the force expressed by one-horse power, the evaporation per minute must develop a mechanical force equal to 52,000 lbs., or about 13 tons raised 400 ft. high. Fifteen cubic inches of water would accordingly produce this effect, which, without evaporation, would be equivalent to 900 cubic inches per hour. To find, therefore, the gross power developed by a boiler, it would be only necessary to divide the number of cubic inches of water evaporated per hour by 900. If, therefore, to 900 cubic inches be added the quantity of water per hour necessary to move the engine itself, independently of its load, we shall obtain the quantity of water per hour which must be supplied by the boiler to the engine for each horse power, and this will be the same whatever may be the magnitude or proportions of the cylinder. In the application of steam power, the most economical means have been attained in the pumping engines of Cornwall, where the steam is employed expansively. The following Tables will show the value of the Cornish engines.

**General Table of the Action of Cornish Steam Engines.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>in lbs.</td>
<td>23</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>in lbs.</td>
<td>112</td>
<td>114</td>
<td>115</td>
<td>118</td>
<td>125</td>
<td>127</td>
</tr>
<tr>
<td>Gallons of water drawn per minute</td>
<td>123</td>
<td>8</td>
<td>53</td>
<td>7</td>
<td>13</td>
<td>159</td>
</tr>
<tr>
<td>Average duty—being million lbs. lifted 1 foot high by the consumption of 1 cwt. of coals</td>
<td>3,773</td>
<td>3,600</td>
<td>3,712</td>
<td>4,001</td>
<td>4,316</td>
<td>4,409</td>
</tr>
<tr>
<td>Actual horse-power employed</td>
<td>1798</td>
<td>1793</td>
<td>1975</td>
<td>1958</td>
<td>1585</td>
<td>1546</td>
</tr>
<tr>
<td>Average consumption of coals per horse-power per horse, in lbs.</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>Number reported</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Number of bibles drawn</td>
<td>1304</td>
<td>1305</td>
<td>1313</td>
<td>1292</td>
<td>1217</td>
<td>1303</td>
</tr>
</tbody>
</table>

**Average of Cornish Steam Engines.**

<table>
<thead>
<tr>
<th>No. of pumping engines.</th>
<th>Quantity of coal consumed</th>
<th>Water lifted in fathoms high.</th>
<th>Average duty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>27</td>
<td>2,285</td>
<td>22,000,000</td>
</tr>
<tr>
<td>February</td>
<td>31</td>
<td>2,540</td>
<td>25,000,000</td>
</tr>
<tr>
<td>March</td>
<td>28</td>
<td>5,333</td>
<td>20,000,000</td>
</tr>
<tr>
<td>April</td>
<td>27</td>
<td>2,668</td>
<td>25,000,000</td>
</tr>
<tr>
<td>May</td>
<td>27</td>
<td>2,333</td>
<td>22,000,000</td>
</tr>
<tr>
<td>June</td>
<td>27</td>
<td>2,544</td>
<td>24,000,000</td>
</tr>
<tr>
<td>July</td>
<td>26</td>
<td>1,917</td>
<td>18,000,000</td>
</tr>
<tr>
<td>August</td>
<td>26</td>
<td>1,780</td>
<td>15,000,000</td>
</tr>
<tr>
<td>September</td>
<td>25</td>
<td>2,033</td>
<td>15,000,000</td>
</tr>
<tr>
<td>October</td>
<td>25</td>
<td>1,618</td>
<td>14,000,000</td>
</tr>
<tr>
<td>November</td>
<td>26</td>
<td>2,168</td>
<td>19,000,000</td>
</tr>
<tr>
<td>December</td>
<td>25</td>
<td>1,923</td>
<td>17,000,000</td>
</tr>
</tbody>
</table>

*The average duty in fifth column gives the number of lbs. lifted one foot high by the consumption of a bushel of coal.*
Abstract of the Duty of Pumping Engines in Cornwall.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of engines repaired</th>
<th>Average duty</th>
<th>Best engine</th>
<th>Description</th>
<th>Engineers</th>
<th>Highest duty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1822</td>
<td>52</td>
<td>29,000,000</td>
<td>Wheal Abraham</td>
<td>Double cylinder</td>
<td>Woolf</td>
<td>47,200,000</td>
</tr>
<tr>
<td>1823</td>
<td>52</td>
<td>32,000,000</td>
<td>Polyphant</td>
<td>60-in. cylinder</td>
<td>Sims</td>
<td>46,000,000</td>
</tr>
<tr>
<td>1825</td>
<td>56</td>
<td>32,500,000</td>
<td>Wheal Vor</td>
<td>Do</td>
<td>Do</td>
<td>34,000,000</td>
</tr>
<tr>
<td>1826</td>
<td>51</td>
<td>30,500,000</td>
<td>Wheal Townan</td>
<td>Do</td>
<td>Do</td>
<td>26,000,000</td>
</tr>
<tr>
<td>1827</td>
<td>57</td>
<td>35,000,000</td>
<td>Wheal Vor</td>
<td>Do</td>
<td>Do</td>
<td>24,000,000</td>
</tr>
<tr>
<td>1829</td>
<td>54</td>
<td>41,700,000</td>
<td>Wheal Vor</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1830</td>
<td>56</td>
<td>45,100,000</td>
<td>Wheal Vor</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1831</td>
<td>58</td>
<td>45,400,000</td>
<td>Wheal Vor</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1832</td>
<td>50</td>
<td>45,000,000</td>
<td>Do</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1833</td>
<td>52</td>
<td>46,000,000</td>
<td>Fowey Consols</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1834</td>
<td>51</td>
<td>47,800,000</td>
<td>Do</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1835</td>
<td>61</td>
<td>45,000,000</td>
<td>Wheat Darlington</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1836</td>
<td>58</td>
<td>45,000,000</td>
<td>Fowey Consols</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1837</td>
<td>61</td>
<td>50,000,000</td>
<td>Wheat Darlington</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1839</td>
<td>52</td>
<td>57,000,000</td>
<td>Fowey Consols</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1840</td>
<td>54</td>
<td>54,000,000</td>
<td>Wheat Darlington</td>
<td>Do</td>
<td>Do</td>
<td>23,000,000</td>
</tr>
<tr>
<td>1841</td>
<td>56</td>
<td>54,500,000</td>
<td>United Mines</td>
<td>55-in. cylinder</td>
<td>Hocking &amp; Loan</td>
<td>101,000,000</td>
</tr>
<tr>
<td>1843</td>
<td>56</td>
<td>55,000,000</td>
<td>Do</td>
<td>Do</td>
<td>Do</td>
<td>101,000,000</td>
</tr>
<tr>
<td>1845</td>
<td>58</td>
<td>60,000,000</td>
<td>Do</td>
<td>Do</td>
<td>Do</td>
<td>101,000,000</td>
</tr>
</tbody>
</table>

In an inquiry upon the incrustations of the boilers of steam vessels, by M. Couste, it is stated that 8 or 10 per cent. of the heat of fuel is lost after the first few days' work—at Bordeaux 15 per cent., and at Havre, after some days' constant work and observation, 40 per cent.; in general practice it has been estimated that 40 per cent. of the heat of the fuel has been lost by the internal incrustations and deposits in the boilers of steam vessels.

The following results were obtained from French ocean steamers:

<table>
<thead>
<tr>
<th>Stations</th>
<th>Sulphate of Lime</th>
<th>Carbonate of Magnesia</th>
<th>Free Magnesia</th>
<th>Iron and Alumina</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>(partly crystallized)</td>
<td>84-90</td>
<td>2-25</td>
<td>5-65</td>
<td>-</td>
<td>6-5</td>
</tr>
<tr>
<td>Mediterranean, tubular boiler (amorphous deposit)</td>
<td>84-94</td>
<td>2-24</td>
<td>7-66</td>
<td>0-41</td>
<td>4-65</td>
</tr>
<tr>
<td>Mediterranean, (amorphous deposit)</td>
<td>80-90</td>
<td>2-19</td>
<td>10-52</td>
<td>6-55</td>
<td>4-56</td>
</tr>
</tbody>
</table>

An essential character of the sea-water incrustations is that they are free from the deposit of calcareous carbonates.

STEEL (Acier, Fr.; Stahl, Germ.) is a carburet of iron, more or less freed from foreign matter, and may be produced by two processes opposed to each other. First, by working pig iron, which contains 4 or 5 per cent. of carbon, in a suitable furnace, until such carbon is reduced to that quantity required for constituting steel, which is about 1 per cent.; the second method is to heat iron bars in contact with charcoal, until they have absorbed that quantity of carbon which may be required.

Steel may be classed into three kinds:—
1st. Natural steel, which is manufactured from pig iron direct.
2d. Cemented or converted steel, which is produced by the carbonization of wrought iron.
3rd. Cast steel, which is produced by the fusion of either natural or cemented steel, but principally from the latter.

The various kinds of iron which are used for the manufacture of steel are imported principally from Sweden, Norway, and Russia; but the high price of Swedish and other steel iron has for the past few years compelled the consumers to look elsewhere for a supply of foreign-made iron, whilst at the same time every encouragement has been offered to English manufacturers so to improve their steel irons as to render them at least suitable for the production of steel good enough for the manufacture of coach springs and such other purposes.

England now furnishes a large quantity of iron suitable for steel purposes, which may be estimated at 20,000 tons per annum; this iron is manufactured with great care, often with an admixture of charcoal pig iron, and various chemical reagents, which are added at the caprice of each manufacturer, but the object of which is to discharge the deleterious matters and to reduce the semi-metals.

It is of the highest importance that the iron used for steel purposes should be as pure and free from foreign matters as possible; those irons which at present enjoy the highest reputation are those manufactured from the Dannemora ores in Sweden; the whole of the steel iron produced in that country are smelted from the black oxides, containing usually 60 per cent. of metal.

Natural or German steel is so called because it is produced direct from pig iron, the result of the fusion of the spathose iron ores alone, or in a small degree mixed with the
brown oxide; these ores produce a highly crystalline metal, called spiegel-eisen on account of the large crystals the metal presents. This crude iron contains from 4 to 5 per cent. of carbon, and 4 to 5 per cent. of manganese. Karsten, Hassengratz, Marcher, and Reau'mur, all advocate the use of gray pig iron for the production of steel; indeed they distinctly state that the best qualities cannot be produced without it; they state correctly that the object of working it in the furnace is to clear away all foreign matters, but there can be no advantage gained by retaining the carbon, and combining it with the iron. This theory is incorrect, although it is supported by such high authorities; gray iron contains the maximum quantity of carbon, and consequently remains for a longer time in a state of fluidity than iron containing less carbon; the metal is not only mixed up with the foreign matter it may itself contain, but also that with which it may become mixed in the furnace in which it is worked. This prolonged working, which is necessary in order to bring highly carbonized metal into a malleable state, increases the tendency to produce silicatized oxides; these mixing with the steel produced render it red short, and destroy many good qualities which the pig iron may have originally possessed. The semi-metals produced tend also to prevent malleability; the use of highly carbonized white pig iron is equally inapplicable, and causes a large consumption of charcoal, as well as waste of metal. In Austria, where a large quantity of natural steel is produced, the fluid metal is tapped from the blast furnace into a round hole; water is sprinkled on the surface, which chills it, and thus forms a cake about half an inch thick. This is taken from the surface, and the operation is again performed until the whole is formed into cakes; they are then piled edgewise in a furnace, and covered with charcoal, and heated a full red heat for about 48 hours; by this process much of the carbon is discharged. These cakes are then used for producing steel in the refinery. A much superior quality is thus obtained with greater economy. It appears that the most perfect plan for manufacturing the steel is to free the crude metal as much as possible from its impurities whilst in a fluid state. There is a process patented by Mr. Charles Sanderson of Sheffield, which fulfils all that is required. The crude metal is melted on the bed of a reverberatory furnace, and any chemically reagent is added capable of disengaging oxygen during its decomposition. Carbonic acid or carbonic oxide gases are produced by the union of the oxygen with the carbon contained in the fluid iron, which is thus eliminated; the gases so produced, being unable to enter the metal, either pass off in vapor, or act upon the silicates or other earthy compounds which the crude iron may contain, precipitating the metallic part and allowing the earthy matter to flow away as slag: a refined metal is thus produced of very great purity for the production of steel. The metal itself being to some extent decarbonized, the steel is more quickly produced, which secures economy in charcoal, time, and waste of metal, &c.; the purity of the metal also prevents the formation of those deleterious compounds, which, when they are incorporated with the steel, seriously injure the quality. Natural steel manufactured from this purified iron has been found of very superior quality, and more uniform. The furnaces used for the production of natural steel are like the refineries in which charcoal iron is produced. In all countries their general construction is the same, but each has its own peculiar mode of working. We find, therefore, the German, the Styrian, the Carinthian, and several other distinct methods, yet all producing steel from crude iron directly, although pursuing different modes of operation. These differences arise from the nature of the pig iron each country produces, and the peculiar habits of the workmen. These modified processes do not affect the theory of the manufacture of the steel, but rather accommodate themselves to the peculiar character of the metal produced. 

Fig. 614 shows a ground plan of the furnace; fig. 615 an elevation; and fig. 616 the form of the fire itself and the position of the metal within it. The fire, d, is 24 inches long and 24 inches wide; a, a, a are metal plates, surrounding the furnace. Fig. 615 shows the elevation, usually built of stone, and braced with iron bars. The fire, c, is 16 inches deep and 24 inches wide; before the tuyère, at a, a space is left under the fire, to allow the damp to escape, and thus keep the bottom dry and hot. In fig. 614 there are two tuyères, but only one tuyère iron, which receives both, the blast nozzles, which are so laid and directed that the currents of air cross each other, as shown by the dotted lines; the blast is kept as regular as possible, so that the fire may be of one uniform heat, whatever intensity may be required. Fig. 616 shows the fire itself, with the charcoal, and blast. a is a bottom of charcoal, rammed down very close and hard. b is another bottom, but not so closely beaten down; the bed of charcoal protects the under one, and serves also to give out carbon to the loop of steel during its production. c is a thin stratum of metal, which is kept in the fire to surround the loop. D shows the loop itself in progress. When the fire is hot, the first operation is to melt down a portion of pig iron, say 50 to 70 pounds according as the pig contains more or less carbon; the charcoal is pushed back from the upper part of the fire, and the blast, which is then reduced, is allowed to play upon the surface of the metal, adding from time to time some hammer slack, or rich cinder, the result of the previous loop. All these operations tend to decarbonize the metal to a
certain extent; the mass begins to thicken, and at length becomes solid. The workman then draws together the charcoal and melts down another portion of metal upon the cake; this operation renders the face of the cake again fluid, but the operation of decarboni-

**STEEL.**

This operation, apparently so simple in itself, requires both skill and care; the workman has to judge, as the operation proceeds, of the amount of carbon which he has retained from the pig iron; if too much, the result is a very raw, crude, untreatable steel; if too little, he obtains only a steelified iron; he has also to keep the cinder at a proper degree of fluidity, which is modified from time to time by the addition of quartz, old slags, &c. It is usual to keep from two to three inches of cinder on the face of the metal, to protect it from the direct action of the blast. The fire itself is formed of iron plates, and the two charcoal bottoms rise to within nine inches of the tuyère, which is laid flatter than when iron is being made. This position of the tuyère causes the fire to work more slowly, but it insures a better result.

The quantity of blast required is about 180 cubic feet per minute. Good workmen make 7 cwt. of steel in 17 hours. The waste of the pig iron is from 20 to 25 per cent., and the quantity of charcoal consumed is 240 bushels per ton. The inclination of the tuyère is 12 to 15 degrees. The flame of the fire is the best guide for the workmen. During its working it should be a red bluish color. When it becomes white the fire is working too hot.

From this description of the process, it will be evident that pig iron will require a much longer time to decarbonize than the cakes of metal which have been roasted, as already described; and, again, it must be evident, that a purified and decarbonized metal must be the best to secure a good and equal quality to the steel, since the purified metal is more homogeneous than the crude iron.

When, therefore, care has been taken in melting down each portion of metal, and a complete and perfect layer of steel has been obtained after each successive melting; when the cinder has had due attention, so that it has been neither too thick nor too thin, and the
STEEL.

heat of the fire regulated and modified during the progressive stages of the process, then a good result is obtained; a fine-grained steel is produced, which draws under the hammer, and hardens well. However good it may be, it possesses one great defect; it is this: during its manufacture, iron is produced along with the steel, and becomes so intimately mixed up with it, that it injures the otherwise good qualities of the steel; the iron becomes, as it were, interlaced throughout the mass, and thus destroys its hardening quality. When any tool or instrument is made from natural steel, without it has been well refined, it will not receive a permanent cutting edge; the iron part of the mass, of course, not being hard, the tool cuts only upon the steel portion; the edge, therefore, very soon becomes destroyed. There is another defect in natural steel, but it is of less importance. When too much carbon has been left, the steel is raw and coarse, and it draws very imperfectly under the hammer; the articles manufactured from such steel often break in hardening; thus it is evident that, in producing this kind of steel, every care, skill, and attention is required at the hands of the workman. These defects very materially affect the commercial value of the steel; the irregular quality secures no guarantee to the consumer that the tools shall be perfect, and, consequently, it is not used for the most important purposes; yet, when the raw steel is refined, it becomes a very useful metal, and is largely used in Westphalia for the manufacture of hardware, scythes, and even swords. It possesses a peculiarity of retaining its steel quality after repeated heating. This property renders it very useful for mining and many other purposes.

The raw steel, being so imperfect, is not considered so much an article of commerce with the manufacturer, but it is sold to the steel refiners, who submit it to a process of welding. The raw steel bloom is drawn into bars, one or two inches wide and half an inch thick, or less; a number of these are put together and welded; these bars are then thrown into water, and they are broken in smaller pieces to examine the fracture; these bars which are equally steelified are mixed together. In manufacturing refined steel, the degree of hardness is selected to suit the kind of article which it is intended to make. A bar, two to three feet long, forms the top and bottom of the bundle, but the inside of the packet is filled with the small pieces of selected steel. This packet is then placed in a hollow fire, and carefully covered from time to time with pounded clay, to form a coat over the metal, and preserve it from the oxidizing influence of the blast. When it is at a full welding heat it is placed under a hammer, and made as sound and homogeneous as possible; it is again cut, doubled together, and again welded. For very fine articles, the refining is increased by several doublings, but this is not carried at present to so great an extent as formerly, since east steel is substituted, being in many cases cheaper. Although the refined natural steel is very largely consumed in Germany, and also in Austria, yet a considerable quantity is exported to South America, the United States, and to Mexico. The Levant trade takes a large portion, and is supplied from the Styrian and Carinthian forges. This is shipped from Trieste; it is sold in boxes and bundles. That in boxes is marked No. 60, up to 4. The 00 is the smallest, being about 1/2 in. square; number 4 is about 5 in.; 0, 1, 2, and 3 being the intermediate sizes. It is broken into small pieces, about 5 to 7 inches long. In bundles of 100 lbs., the steel is drawn to various sizes, and is packed. A large portion is sent to the East Indies, and also to the United States.

The average price of that sold in boxes is £20 to £24 per ton; in bundles, £17 to £20; and the raw steel, as sold to the refiners, £15 to £18 per ton; whilst the refined steel increases in price according to the number of times it has been refined.

Natural steel being expensive, many attempts were made in Westphalia to produce a kind of steel by puddling pig iron in a peculiar manner; a patent was taken out in England by Mr. Riepe, and a considerable quantity of this steel is produced. In Mr. Riepe's description of this process he says:

"I employ the puddling furnace in the same way as for making wrought iron. I introduce a charge of about 280 lbs. of pig iron, and raise the temperature to redness. As soon as the metal begins to fuse and trickle down in a fluid state, the damper is to be partially closed in order to temper the heat. From 12 to 16 shovelfuls of iron cinder discharged from the rolls or squeezing machine are added, and the whole is to be uniformly melted down. The mass is then to be puddled with the addition of a little black oxide of manganese, common salt, and dry clay, previously ground together. After this mixture has acted for some minutes, the damper is to be fully opened, when about forty pounds of pig iron are to be put into the furnace, near the fire bridge, upon elevated beds of cinder prepared for that purpose. When this pig iron begins to trickle down, and the mass on the bottom of the surface begins to boil and throw out from the surface the well-known blue jets of flame, the said pig iron is raked into the boiling mass, and the whole is then well mixed together. The mass soon begins to swell up, and the small grains begin to form in it and break through the melted cinder on the surface. As soon as these grains appear, the damper is to be three-quarters shut, and the process closely inspected, as the mass is being puddled to and fro beneath the covering layer of cinder. During the whole of this process the heat should not be raised above cherry redness, or the welding heat of shea
steel. The blue jets of flame gradually disappear, while the formation of grains continues, which grains very soon begin to fuse together, so that the mass becomes very and has the above mentioned cherity redness. If these precautions are not observed, the mass would pass more or less into iron, and no uniform steel product could be obtained. As soon as the mass is finished or fair, the fire is stirred to keep the necessary heat for the succeeding operation—the damper is to be entirely shut, and part of the mass is collected into a ball, the remainder always being kept covered with cinder-sack. This ball is brought under the hammer, and then worked into bars. The same process is continued until the whole is worked into bars. When I use pig iron made from sparry iron ore, or mixtures of it with other pig iron, I add only about 20 lbs. of the former pig iron at the later period of the process instead of about 40 lbs. When I employ Welsh or pig iron of that description, I throw 10 lbs. of best plastic clay, in a dry granulated state, before the beginning of the process, on the bottom of the furnace. I add at the later period of the process, about 40 lbs. of pig iron, as before described, but stew over it clay in the same proportion as just mentioned. This steel is very useful for ships' plates, being very strong and rigid, and thus requiring less weight of metal; it may also eventually be used for rails and a great variety of purposes, for which at present strong charcoal or scrap iron is used. Its present price is about £25 in plates, and £16 in bars.

The Paal process may be considered as an improvement upon natural steel, the object being as far as possible to carbonize the iron fibres which this kind of steel always contains. The process is based upon the old one of Vanneck; it consists in plunging iron into a bath of melted metal. The carbon of the metal combines with the iron, and in a very short time converts it into steel. This process was worked further by Vanneck, who contrived to add wrought iron to the metal until he had decarbonized it sufficiently; this was found to produce a steel, but unfit for general use. That produced by plunging iron into metal was found to be very hard steel on the outside, but iron within; while that produced by adding iron to the metal was found too brittle to be drawn. The Paal method, however, is a decided improvement in the manufacture of refined natural steel. The packets, as already described in the refinement of natural steel, are welded and drawn to a bar; whilst hot, they are plunged into a bath of metal for a few minutes, by which the iron contained in the raw steel becomes carbonized, and thus a more regular steel is obtained than that produced by the common process. The operation requires great care, for if the bars of steel be left in the metal too long, they are more or less destroyed, or perhaps entirely melted. It commands a little higher price in the market, and is chiefly consumed by the home manufacturers, excepting a portion which is exported to Russia.

The foregoing kinds of steel may be classed under the first head of natural steel, being manufactured from the crude iron direct.

The next process is the production of steel by introducing carbon into malleable iron, which is the reverse of the process already described. The iron to be converted is placed in a furnace, stratified with carbonaceous matter, and on heat being applied the iron absorbs the carbon, and a new compound is thus formed. When this process was discovered is not known; at a very early period charcoal was found to harden iron, and to give it a better and more permanent cutting edge. It seems probable that from hardening small objects, bars of iron were afterward submitted to the same process. To Reaumur certainly belongs the merit of first bringing the process of conversion to any degree of perfection. His work contains a vast amount of information upon the theory of cementation; and although his investigations are not borne out by the practice of the present day, yet the first principles laid down by him are now the guide of the converter. Our furnaces are much larger than those used by Reaumur, and they are built so as to produce a more uniform and economical result. The furnace of cementation in which bar iron is converted into blistered steel is represented in figs. 617, 618, 619.
It is rectangular, and covered in by a semicircular arch, in the centre of which there is a circular hole left, 12 inches diameter, which is opened when the furnace is cooling. It contains two chests called "pots," c, c, made either of fire-stone or fire-bricks; each "pot" is 9 feet wide, 5 feet deep, and 12 feet long. One is placed on one side, and the other on the contrary side of the fire-grate, A, n, which occupies the whole length of the furnace, and is 13 to 14 feet long; the grate is 15 to 16 inches broad, and the bars rest from 10 to 12 inches below the inferior plane or bottom level of the "pots;" the height of the arch at the centre is 51 feet above the top of the "pots," the bottoms of which are nearly level with the ground, so that the bars of iron do not need lifting so high when charging them into the furnace. The flames rise between the two "pots;" it passes also below and around them, through the horizontal and vertical flues, d, and issues from the furnace through the six small chimneys, n, into a large conical space which is built around the whole furnace, 20 to 40 feet high, open at the top. This cone increases the draft of the furnace, and carries away the smoke. There are three openings in the front of the arch; two, r, fig. 619, above the pots, serve to admit and remove the bars; they are about 8 inches square; in each a piece of iron is placed upon which the bars slide in and out of the furnace. The workman enters by the middle opening, r, to arrange the bars, which he lays flat in the pots, and spreads a layer of charcoal, ground small, between each layer; the bars are laid near each other, excepting those nearest to the side of the pot, which are placed an inch from it; the last stratum of iron is covered with a thick layer of charcoal, and the whole is carefully covered with loamy earth 4 to 5 inches thick. The iron is gradually heated, in about 4 days has become fully heated through, and the furnace has then attained its maximum heat, which is maintained for 2 or 3 days until the first test bar is drawn out; the heat is afterward regulated, according to the degree of hardness which may be required. The iron is converted in 8 days if for soft steel, and in 9 to 11 days if for harder purposes.

Conversion usually commences in 60 to 70 hours after the furnace is lighted. The pores of the iron being opened by heat, the carbon is gradually absorbed by the mass of the bar, but the carbonization or conversion is effected, as it were, in layers. To explain the theory in the clearest manner, suppose a bar to be composed of a number of lamina—the combination of the carbon with the iron is first effected on the surface, and gradually extends from one lamina to another, until the whole is carbonized. To effect this complete carbonization the iron requires to be kept at a considerable uniform heat for a length of time. Thin bars of iron are much sooner converted than thick ones. Reaumur states, in his experiments, that if a bar of iron 1/16 of an inch thick is converted in 6 hours, a bar 1/8 of an inch would require 36 hours to attain the same degree of hardness. The carbon introduces itself successively: the first lamina or surface of a bar, combining with a portion of the carbon with which it is in contact, gives a portion of the carbon to the second lamina, at the same time taking up a fresh quantity of carbon from the charcoal; these successive combinations are continued until the whole thickness is converted; from which theory it is evident that from the exterior to the centre the dose of carbon becomes proportionately less. Steel so produced cannot be said to be perfect; it possesses in some degree the defect of natural steel, being more carbonized on the surface than at the centre of the bar. From this theory we perceive that steel made by cementation is different in its character from that produced directly from crude metal. In conversion the carbon is made successively to penetrate to the centre of the bar, whilst in the production of natural steel, the molecules of metal which compose the mass are per se charged with a certain percentage of carbon necessary for their stedification; not imbied, but obtained by the decarbonization of the crude iron down to a point requisite to produce steel.

During the process of cementation, the introduction of the carbon disintegrates the molecules of the metal, and in the harder steel produces a distinct crystallization of a white silvery color. Wherever the iron is unsound or imperfectly manufactured, the surface of the steel becomes covered with blisters thrown up by the dilution of the metal and introduction of carbon between those lamina which are imperfectly welded. Reaumur and others have attributed this phenomenon to the presence of sulphur, various salts, or zinc, which dilute the metal; but this is incorrect, because we find that a bar of cast steel which is homogeneous and perfectly free from internal imperfections never blisters; although it receives the highest dose of carbon in the furnace, yet the surface is perfectly smooth. From this it is evident that the blisters are occasioned by imperfections in the iron.
increases, both in length and weight, during conversion. Hard iron increases less than soft. The augmentation in weight may be said to be \( \frac{1}{2} \) per cent, and in length \( \frac{1}{4} \) per cent, on an average.

The operation of conversion is extremely simple in its manipulation; nevertheless, it requires great care, and a long as well as a varied experience, to enable a manager to produce every kind or temper required by consumers. Considerable knowledge is required to ascertain the nature of the irons to be converted, because all irons do not convert equally well under the same circumstances; some require a different treatment from others, and, again, one iron may require to be converted at a different degree of heat from another. The furnace must have continual care, and be kept air-tight, so that the steel, when carbonized, may not again become oxidized. It is known amongst steel-makers, that if iron be brought in contact with carbon, and if heat be applied, it will become steel. This is the knowledge gleaned up by workmen, and also by too many owners of converting furnaces. The inconvenience arising from a want of care and knowledge of the peculiar state of the iron during its conversion, sometimes occasions great disappointment and loss. The success usually attained by workmen may, however, be attributable to an every-day attention to one object, thus gaining their knowledge from experience alone. The conversion or carbonization of the iron is the foundation of steel-making, and, as such, may be considered as the first step in its manufacture. Before bar steel is used for manufacturing purposes, it has to be heated, and hammered or rolled. Its principal uses are for files, agricultural implements, spades, shovels, wire, &c., and in very large quantities for coach springs.

Bar steel is also used for manufacturing shear steel. It is heated, drawn to lengths 3 feet long, then subjected to a welding heat, and some six or eight bars are welded together, precisely as described in the refinement of natural steel; this is called single shear. It is further refined by doubling the bar, and submitting it to a second welding and hammering; the result is a dearer and more homogeneous steel. During the last seven years the manufacture of this steel has been limited, mechanics preferring a soft cast steel, which is much superior, when properly manufactured, and which can be very easily welded to iron.

The price of bar steel varies according to the price of the iron from which it is made; but, as a general average, its price in commerce may be taken at £2 per ton beyond the price of the iron from which it is made. Bar steel produced from the better irons is usually dearer than the commoner kind, on account of their scarcity.

Shear steel in ordinary size sells at £20 per ton net.

Coach-spring steel from foreign iron, £32

Coach-spring steel from English iron, £18

These may be taken as approximate prices in 1859-60.

Both natural, puddled, and converted steel have great defects in temper, clearness, and uniformity, and are unfit for most useful purposes. To obviate these defects, these steels are broken in pieces and melted in a crucible, thus freeing them from any deleterious matter they might contain; equality in texture and degree of hardness is thus obtained, whilst the steel is also capable of receiving a clear and beautiful polish.

The process of melting bar steel, and thus producing cast steel, was first practically carried on by Mr. Huntsman, of Attercliffe; the process itself is very simple. Fig. 620 shows a cross section of the furnace universally used.

The furnace \( \text{a} \) is square, lined with fire-stone 12 inches by 22 wide, and 36 inches deep from the grate bar to the under side of the cover \( \text{b} \). \( \text{c} \) is a crucible, of which two are placed in one "melting hole." \( \text{d} \) is the flue into the chimney \( \text{e} \), which is about 40 feet high, lined with fire-brick. There is an air flue which is used to regulate the draught at \( \text{f} \). \( \text{g} \) is the ash pit, and \( \text{h} \) is the cellar, which is arched over.

The steel is broken in pieces and charged into the crucible, which is placed on a stand and provided with a cover; coke is used as a fuel, and an intense heat is obtained. The crucible is charged three times during the day, and is then burnt through; the first charge
is usually 36 lbs., which requires from three to fouh hours to melt it; the second charge is about 32 lbs., which is melted in about three hours; the last charge is 28 to 30 lbs., which does not require more than two to two and a half hours to become perfectly melted. The consumption of coke averages 3½ tons per ton of cast steel. When the steel is completely fluid, the crucible is drawn from the furnace, and the steel poured into a cast-iron mould; the result is an ingot, which is subsequently rolled or hammercd, according to the want of the consumer.

Although the melting of cast steel is a simple process, yet, on the other hand, the manufacture of cast steel suitable for the various wants of those who consume it requires an extensive knowledge of a art; a person who is capable of successfully conducting a manufacture, must make himself master of the treatment to which the steel in manufactures will be submitted by every person who consumes it. Cast steel is not only made of many degrees of hardness, but it is also made of different qualities; a steel-maker, therefore, to combine a very intimate knowledge of the exact intrinsic quality of the iron he uses, or that produced by a mixture of two or three kinds together; he has to secure as complete and as equal a degree of carbonization as possible, which can only be attained by possessing a perfect practical and theoretical knowledge of the process of converting; he has to know that the steel he uses is equal in hardness, in which, without much practice, he may easily be deceived; he must give his own instructions for its being carefully melted, and he must examine its fracture by breaking off the end of each ingot, and exercise his judgment whether or not proper care has been taken; besides all this knowledge and care, a steel-maker has to adapt the capabilities of his steel to the wants and requirements of the consumer. There are a vast variety of defects in steel as usually manufactured; but there are a far greater number of instances in which steel is not adopted for the manufacture of the article for which it was expressly made. Cast steel may be manufactured for planing, boring, or turning tools; its defects may be, that the tools, when made, crack in the process of hardening, or that the tool, whilst exceedingly strong in one part, will be found in another part utterly useless.

Cast steel may be wanted for the engraver. It may be produced apparently perfect, and with a clear surface, but may be so improperly manufactured, that when the plate has been engraved and has to be hardened, it is found covered with soft places. The trial is even greater when the engraving is transferred by pressure to another plate. It is, therefore, evident that a steel-maker must not only attend to the intrinsic quality of his steel, but he has to use his judgment as regards the degree of hardness and tenacity which it should possess, so as to adapt it to the peculiar requisites of its employment.

The manufacture of cast steel is open to great temptations, which may be termed fraudulent. Swedish iron, as I have already stated, varies in price according to its usefulness for steel purposes; cast steel may, therefore, be manufactured from a metal selling at £20 per ton, whilst the price charged for it to the consumer presume it to have been made from a metal worth £30 per ton. The exterior of the bar is perfect, the fracture appears to the eye satisfactory, and its intrinsic value is only discovered when it is put to the test; thus, whilst a steel-maker has to exercise his knowledge, judgment, and care, he has a moral duty to perform, by giving to his customer a metal of the intrinsic value he professes it to be, and for which he makes his charge.

In manufacturing the commonest description of steel, particularly cast steel made from English iron, black oxide of manganese is added to the steel in the crucible, and acts as a detergent. The oxygen unites with a portion of the carbon in the steel, forming carbonic oxide gas, which acts upon the imperfectly metallic portions of the steel used, and liberates the metal, whilst the deleterious matter is taken up and forms a slag with the manganese. There has been a great controversy regarding the invention which originated with Mr. Heath. This substance is not generally used when the Dumenorn irons are melted, as they are very pure, and the addition of an oxide partially destroys the temper of the steel. The Indian steel, or wootz, is also a cast steel.

Indian steel, or wootz.—The wootz ore consists of the magnetic oxide of iron, united with quartz, in proportions which do not seem to differ much, being generally about 42 of quartz and 58 of magnetic oxide. Its grains are of various sizes, down to a sandy texture. The natives prepare it for smelting by pounding the ore, and winnowing away the stony matrix, a task at which the Hindoo females are very dexterous. The manner in which iron ore is smelted and converted into wootz or Indian steel, by the natives at the present day, is probably the very same that was practised by them at the time of the invasion of Alexander; and it is a uniform process, from the Himalaya mountains to Cape Comorin. The furnace or bloomery in which the ore is smelted is from 4 to 5 feet high; it is somewhat pear-shaped, being about 2 feet wide at bottom, and 1 foot at top; it is built entirely of clay, so that a couple of men can finish its erection in a few hours, and have it ready for use the next day. There is an opening in front about a foot or more in height, which is built up with clay at the commencement, and broken down at the end of each smelting operation. The bellows are usually made of a goat's skin, which has been stripped from the animal without ripping open the part covering the belly. The apertures at the legs are
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The handful drawn and converted, each by the hand, and kept close together in making the stroke for the blast; in the returning stroke they are separated to admit the air. By working a bellows of this kind with each hand, making alternate strokes, a pretty uniform blast is produced. The bamboo nozzles of the bellows are inserted into tubes of clay, which pass into the furnace at the bottom corners of the temporary wall in front. The furnace is filled with charcoal, and a lighted coal being introduced before the nozzles, the mass in the interior is soon kindled. As soon as this is accomplished, a small portion of the ore, previously moistened with water, to prevent it from running through the charcoal, but without any flux whatever, is laid on the top of the coal, and covered with charcoal to fill up the furnace.

In this manner ore and fuel are supplied; and the bellows are urged for 3 or 4 hours, when the process is stopped; and the temporary wall in front being broken down, the bloom is removed by a pair of tongs from the bottom of the furnace. It is then beaten with a wooden mallet, to separate as much of the scorzie as possible from it, and, while still red hot, it is cut through the middle, but not separated, in order merely to show the quality of the interior of the mass. In this state it is sold to the blacksmiths, who make it into bar iron.

The proportion of such iron made by the natives from 100 parts of ore is about 15 parts. In converting the iron into steel, the natives cut it into pieces, to enable it to pack better in the crucible, which is formed of refractory clay, mixed with a large quantity of charred husk of rice. It is seldom charged with more than a pound of iron, which is put in with a proper weight of dried wood chopped small, and both are covered with one or two green leaves; the proportions being in general 10 parts of iron to 1 of wood and leaves. The mouth of the crucible is then stopped with a handful of tempered clay, rammed in very close, to exclude the air. The wood preferred is the Cassia auriculata, and the leaf that of the Asclepias gigantea, or the Convolvulus lancifolius. As soon as the clay plugs of the crucible are dry, from twenty to twenty-four of them are built up in the form of an arch, in a small blast furnace; they are kept covered with charcoal, and subjected to heat urged by a blast for about two hours and a half, when the process is considered to be complete. The crucibles, being now taken out of the furnace and allowed to cool, are broken, and the steel is found in the form of a cake, rounded by the bottom of a crucible. When the fusion has been perfect, the top of the cake is covered with stricke, radiating from the centre, and is free from holes and rough projections; but if the fusion has been imperfect, the surface of the cake has a honeycomb appearance, with projecting lumps of malleable iron. On an average, four or five cakes are more or less defective. These imperfections have been tried to be corrected in London by remelting the cakes, and running them into ingots; but it is obvious that when the cakes consist partially of malleable iron and of unreduced steel, simple fusion cannot convert them into good steel. When care is taken, however, to select only such cakes as are perfect, to remelt them thoroughly, and tilt them carefully into rods, an article has been produced which possesses all the requisites of fine steel in an eminent degree. In the Supplement to the Encyclopaedia Britannica, article Cutlery, the late Mr. Stoddart, of the Strand, a very competent judge, has declared, "that for the purposes of fine cutlery, it is infinitely superior to the best English cast steel."

The natives prepare the cakes for being drawn into bars by annealing them for several hours in a small charcoal furnace, actuated by bellows; the current of air being made to play upon the cakes while turned over before it; whereby a portion of the combined carbon is probably dissipated, and the steel is softened; without which operation the cakes would break in the attempt to draw them. They are drawn by a hammer of a few pounds weight.

Fig. 621 represents the mould for making the crucibles: each manufacturer makes his own; M, M, is a solid block of wood let into the floor, having a hole which admits a round piece of iron fixed in the centre of the plug p. The material of which the crucible is made consists of 32 lbs. of dry clay got from Stannington near Sheffield, from the neighborhood of Burton-on-Trent, or Stourbridge; 2 lbs. of the old crucible after it has been used, ground to powder, and about 7 lbs. of ground coke. These quantities are sufficient for one crucible of the ordinary size. This composition is trodden for 8 or 10 hours on a metal floor; it is then cut into pieces of 26 to 28 lbs.; each piece is rolled round nearly to the size of the mould into which it is introduced, and the plug p is driven down with a mallet; the mould is furnished with a movable bottom: when the pot is made, the mould is lifted up by the two handles, and filling the bottom on the pot, the mould falls, and leaves the crucible upon it. Converted bars, and also cast steel in ingots, are reduced to bars, rods, and sheets by hammering or rolling; when forged, they are heated in a small furnace urged by blast, an I drawn to bars under hammers of 7 to 9 cwt., giving 100 to 120 strokes per minute.
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When small rods are required, they are "tilted," that is, they are heated and drawn under hammers of 3 or 4 cwt., striking 200 to 250 blows per minute. When steel is rolled, the machinery used is of the same construction as that required for rolling iron, excepting that the rollers are usually hard on the surface. Hardening and tempering steel is a delicate operation; small articles of cutlery are usually hardened by first heating them to a red heat and plunging them in water; saws and such articles are, when heated, plunged into oil. All articles are tempered by carefully heating them when hardened, and the degree of temper is indicated by a change in the color of the surface, which is first straw-colored, then blue, and deep blue; color is thus made the most delicate test for the degree of temper given: after this operation steel is found to expand a little. Alloys of steel have been very carefully made by Messrs. Stoddart & Faraday, but no alloy has at present been found to give any addition to the intrinsic quality of steel; the empiric titles of "silver steel," "meteoric steel," etc., may be regarded simply as fanciful names to recommend the article, either as a raw material or in a manufactured state.

Those articles called "run steel" are made by melting pig-iron and pouring it into moulds of sand in which the required article has been moulded; they are then packed in round iron pots about 12 inches diameter, and 16 to 18 inches high, along with hematite iron ore crushed to powder; these pots are packed in a furnace, and heat is applied from 24 hours to several days; the oxygen abstracts the carbon from the metal of which the articles are made, and they become to a certain extent malleable—so much so, that pieces a quarter of an inch thick may be bent almost double, and can be drawn out under a hammer. Forks, table knives, scissors, and many other cheap articles are so made; also a vast variety of parts of cotton and flax machinery are so manufactured, especially those parts which are difficult to forge.

"Damascus" or Damasked "steel," is made by melting together iron and steel, or bars of steel of high and low degrees of carbonization; it may also be produced by melting hard and soft steel in separate crucibles, mixing them together whilst fluid, and immediately pouring the mixture into an ingot mould; the damask is shown by the application of dilute acid to the surface when brightened. The analysis of a genuine Damascus sword-blade has shown that it is not a homogeneous steel, but a mixture of steel and iron.

During the past few years a great many processes have been patented with a view of reducing the cost of cast steel; Mr. Bessemer, Mr. Martyn, Mr. Muses, and others, have suggested modes of producing a serviceable steel from the common pig-iron. A full description of these proposed improvements would take up too much space, but can be examined in the "Repertory of Arts" the whole of these processes are purposely omitted, because a description of them would necessarily demand some examination of their merits.

Statistical account of the manufacture of steel.—The manufacture of steel in England is chiefly confined to Sheffield, although it is also made at Newcastle and in Staffordshire. The importation of Swedish iron, combined with that furnished from English materials, amounts to 40,000 to 50,000 tons per annum; of course this weight represents the quantity of steel manufactured of every description.

The number of furnaces in Sheffield and its neighborhood are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Cast steel Furnaces, or holes.</th>
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</thead>
<tbody>
<tr>
<td>1835</td>
<td>50</td>
</tr>
<tr>
<td>1842</td>
<td>77</td>
</tr>
<tr>
<td>1846</td>
<td>105</td>
</tr>
<tr>
<td>1853</td>
<td>160</td>
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</table>

A converting furnace will produce 300 tons of steel per annum, but if each produce 250 tons, 160 converting furnaces would represent a make of 40,000 tons of steel a year in Sheffield alone. Again, there are 1,405 melting holes; each furnace of 10 holes will melt 200 tons; this, therefore, shows a product annually of 29,000 tons; but as such furnaces may not all be in continual work from various causes, the quantity of cast steel manufactured in Sheffield may be estimated at 23,000 tons—the weight of coach-spring steel, estimated at 10,000 tons, leaving a remainder of 7,000 tons of bar for the manufacture of German, faggot, single and double shear steel. As regards the price, I take cast steel at £45 per ton; its commercial value varies from £35 to £60 per ton net, and as a large quantity of the cheaper steel is sold, £45 per ton is an average. The price of bar steel is below the real value, since it includes all shear steel, the best of which sells at £60 per ton, whilst, however, a portion of this 7,000 tons sells only at £28, and some even lower. The price of coach springs is the price now paid for them.

The statistics of this metal give the following results:

<table>
<thead>
<tr>
<th>Country</th>
<th>Quantity</th>
<th>Average Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>14,954</td>
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</tr>
<tr>
<td>Prussia</td>
<td>5,453</td>
<td>170,824</td>
</tr>
<tr>
<td>Austria</td>
<td>21,677</td>
<td>212,500</td>
</tr>
<tr>
<td>United States</td>
<td>40,000</td>
<td>1,470,000</td>
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</table>
STEEL. 1007

Such is the contrast of the manufacturing power of the steel-producing countries; it shows the eminence position of England, in both weight and value; this can only arise from the practical skill and scientific knowledge which we have brought to bear upon its manufacture, and the active energy which has enabled us to produce steel suitable for every purpose in the arts. This superiority not only enables our manufacturers to maintain the high position they now hold, but to increase it yet further; for we daily see our production expanding, not only to supply the wants of our home manufacturers, but also for the continent of Europe, as well as the United States of America and Canada.

Bessemer's Malleable Iron and Steel.—In the article "Iron," will be found a statement of the process proposed by Mr. Bessemer for converting crude pig-iron into malleable iron, which we believe to be a fair representation of all the facts up to the period when that paper was written. Since then the process has been tried in the manufacture of steel, and, certainly, it appears, with much more success than attended the early experiments made on iron. For the purpose of placing the matter, however, clearly before our readers, I extract a considerable portion of Mr. Henry Bessemer's paper "On the manufacture of malleable Iron and Steel," read before the Institution of Civil Engineers in May last.

"The want of success which attended some of the early experiments was erroneously attributed, by some persons, to the 'burning' of the metal, and by others, to the absence of carbon, and to the crystalline condition of cast metal. It was almost needless to say, that neither of the causes specified had anything to do with the failure of the process, in those cases where failure had occurred. Chemical investigation soon pointed out the real source of difficulty. It was found, that although the metal could be wholly de-carbonized, and the silicium be removed, the quantity of sulphur and of phosphorus was but little affected; and as different samples were carefully analyzed, it was ascertained that red-ness was always produced by sulphur, when present to the extent of one-tenth per cent., and that cold-shortness resulted from the presence of a like quantity of phosphorus; it therefore became necessary to remove those substances. Steam and pure hydrogen gas were tried, with more or less success, in the removal of sulphur, and various fluxes, composed chiefly of silicates of the oxide of iron and manganese, were brought in contact with the fluid metal during the process, and the quantity of phosphorus was thereby reduced. Thus, many months were consumed in laborious and expensive experiments; consecutive steps in advance were made, and many valuable facts were elicited. The successful working of some of the higher qualities of pig-iron caused a total change in the process, to which the efforts of Massey, Bessemer & Longsdon were directed. It was determined to import some of the best Swedish pig-iron, from which steel of excellent quality was made, and tried for almost all the uses for which steel of the highest class was employed. It was then decided to discontinue, for a time, all further experiments, and to erect steel works at Sheffield for the express purpose of fully developing and working the new process commercially, and thus to remove the erroneous impressions so generally entertained in reference to the Bessemer process.

"In manufacturing tool steel of the highest quality, it was found preferable, for several reasons, to use the best Swedish pig-iron, and, when converted into steel by the Bessemer process, to pour the fluid steel into water, and afterward to remelt the cold metal in a crucible, as at present practised in making blister-steel, whereby the small ingots required for this particular article were more perfectly and more readily made.

"It was satisfactory to know that there existed in this country vast, and apparently inexhaustible, beds of the purest ores fitted for the process. Of the haematite alone, 970,000 tons were raised annually, and this quantity might be doubled or trebled, whenever a demanded arose. It was from the haematite pig-iron made at the Workington Iron Works that most of the iron and steel was made. About 1 ton 13 cwt. of ore, costing 10s. per ton, would yield 1 ton of pig metal, with 60 per cent. less lime, and 20 per cent. less fuel, than were generally consumed when working inferior ores; while the furnaces using this ore alone yielded from 230 tons to 240 tons per week, instead of, say, 160 tons to 180 tons per week, when working with common iron-stone. The Cleator Moor, the Weardale, and the Forest of Dean Iron Works also produced an excellent metal for this purpose.

"The form of converting vessel which had been found most suitable somewhat resembled the glass retort used by chemists for distillation. It was mounted on axes, and was lined with 'ganister' or road drift, which lasted during the conversion of thirty or forty charges of steel, and was then quickly and cheaply repaired, or renewed. The vessel was brought into an inclined position, to receive the charge of crude iron, during which time the tuyères were above the surface of the metal. As soon as the whole charge was run in, the vessel was moved on its axes, so as to bring the tuyères below the level of the metal, when the process was at once brought into full activity, and twenty small, though powerful, jets of air sprang upward through the fluid mass; the air, expanding in volume, divided itself into at least fifteen upward, carrying with it a large quantity of the fluid metal, which again fell back into the boiling mass below. The oxygen of the air appeared, in this process, first to produce the combustion of the carbon contained in the iron, and at
the same time to oxidize the silicium, producing silicic acid, which, uniting with the oxide of iron, obtained by the combustion of a small quantity of metallic iron, thus produced a fluid silicate of the oxide of iron, or 'clinker,' which was retained in the vessel and assisted in purifying the metal. The increase of temperature which the metal underwent, and which soon so disproportionate to the quantity of carbon and iron consumed, was doubtless owing to the favorable circumstances under which combustion took place. There was no intercepting material to absorb the heat generated, and to prevent its being taken up by the metal, for heat was evolved at thousands of points, distributed throughout the fluid, and when the metal boiled, the whole mass rose far above its natural level, forming a sort of spongy froth, with an intensely vivid combustion going on in every one of its numberless, ever-changing cavities. Thus, by the mere action of the blast, a temperature was attained, in the largest masses of metal, in ten or twelve minutes, that whole days of exposure in the most powerful furnace would fail to produce.

"The amount of decarbonization of the metal was regulated, with great accuracy, by a meter, which indicated on a dial the number of cubic feet of air that had passed through the metal; so that steel of any quantity or temper could be obtained with the greatest certainty. As soon as the metal had reached the desired point, (as indicated by the dial,) the workmen moved the vessel, so as to pour out the fluid malleable iron or steel into a founder's ladle, which was attached to the arm of a hydraulic crane, so as to be brought readily over the moulds. The ladle was provided with a fire-clay plug at the bottom, the raising of which, by a suitable lever, allowed the fluid metal to descend in a clear vertical stream into the moulds. When the first mould was filled, the plug valve was depressed, and the metal was prevented from flowing until the casting ladle was moved over the next mould, when the raising of the plug allowed this to be filled in a similar manner, and so on until all the moulds were filled.

"The casting of large masses of a perfectly homogeneous malleable metal into any desired form rendered unnecessary the tedious, expensive, and uncertain operation of welding, now employed wherever large masses were required. The extreme toughness and extensibility of the Bessemer iron was proved by the bending of cold bars of iron 8 in. square, under the hammer, into a close fold, without the smallest perceptible rupture of the metal at any part; the bar being extended on the outside of the bend from 12 in. to 16 lb., and being compressed on the inside from 12 in. to 71 in., making a difference in length of 28 in., between what, before bending, were the two parallel sides of a bar 8 in. square. An iron cable, consisting of four strands of round iron 12 in. diameter, was so closely twisted, while cold, as to cause the strands at the point of contact to be permanently imbedded in each other. Each of these strands had elongated 121 in. in a length of 4 ft., and had diminished 416 of an inch in diameter, throughout their whole length. Steel bars, 2 in. square and 2 ft. 6 in. in length, were twisted cold into a spiral, the angles of which were about 45 degrees; and some round steel bars, 2 in. in diameter, were bent cold under the hammer, into the form of an ordinary horse-shoe magnet, the outside of the bend measuring 5 in. more than the inside.

"The steel and iron boiler plates, left without shearing, and with their ends bent over cold, afforded ample evidence of the extreme tenacity and toughness of the metal; while the upper, even surface of railway axles and pieces of malleable iron ordnance were examples of the perfect freedom from cracks, flaws, or hard veins, which forms so distinguishing a characteristic of the new metal. The tensile strength of this metal was not less remarkable, as the several samples of steel tested in the proving machine at Woolwich arsenal bore, according to the reports of Colonel Eardley Wilmot, R.A., a strain varying from 150,000 lbs. to 160,000 lbs. on the square inch, and four samples of iron boiler plate from 63,914 lbs. to 73,100 lbs.; while, according to the published experiments of Mr. W. Fairbairn, Staffordshire plates bore a mean strain of 43,000 lbs.; and Low Moor and Bowling plates a mean of 57,120 lbs. per square inch.

"There was also another fact of great importance in a commercial point of view. In the manufacture of plates for boilers and for shipbuilding, the cost of production increased considerably with the increase of weight in the plate; for instance, the Low Moor Iron Company demanded £22 per ton for plates weighing 2½ cwt. each; but if the weight exceeded 5 cwt., then the price rose from £22 to £37 per ton. Now with cast ingots, such as the one exhibited and from which the sample plates were made, it was less troublesome, less expensive, and less wasteful of material, to make plates weighing from 10 cwt. to 20 cwt., than to produce smaller ones; and indeed there could be but little doubt that large plates would eventually be made in preference, and that those who wanted small plates would have to cut them from the large ones. A moment's reflection would, therefore, show the great economy of the new process in this respect; and when it was remembered that every riveted joint in a plate reduced the ultimate strength of each 100 lbs. to 70 lbs., the great value of long plates for girders and for shipbuilding would be fully appreciated.

"It would be interesting to those who were watching the advancement of the new process, to know that it was already rapidly extending itself over Europe. The firm of Daniel
Elfsand & Co., of Edsken, who were the pioneers in Sweden, had now made several hundred tons of excellent steel by the Bessemer process. Another large manufactory had since been started in their immediate neighborhood, and three other companies were also making arrangements to use the process. The authorities in Sweden had fully investigated the whole process, and had pronounced in favor of it. Large steel circular saw-plates were made by Mr. Göranson, of Göteborg, in Sweden, the ingot being cast direct from the fluid metal within fifteen minutes of its leaving the blast furnace. In France the process had been for some time carried on by the old established firm of James Jackson & Son, at their steel works near Bordeaux. This firm was about to manufacture puddled steel on a large scale. They had already got a puddling furnace erected and in active operation, when their attention was directed to the Bessemer process, the apparatus for which was put up at their works last year; and they were now extending their field of operations, by putting up more powerful apparatus at the blast furnaces in the Landes. There were also four other blast furnaces in the south of France in course of erection, for the express purpose of carrying out the new process.

"The iron of Algeria and Saxony had produced steel of the highest quality.

"Belgium was not much behind her neighbors; the process was now being carried into operation at Liège, where excellent steel had been made from the native coke iron; while in Sardinia preparations were also being made for working the system. Professor Müller, of Vienna, and M. Dumas, from Paris, had visited Sweden, to inspect and report on the working of the new system in that country."

"That the process admitted of further improvement, and of a vast extension beyond its present limits, the author had no doubt; but those steps in advance would, he imagined, result chiefly from the experience gained in the daily commercial working of the process, and would most probably be the contributions of the many practical men who might be engaged in carrying on the manufacture of iron and steel by this system."

The following information is of interest:

Comparative tensile strength of various kinds of Iron and Steel in lbs. per square inch.

<table>
<thead>
<tr>
<th>Kind of Steel</th>
<th>Strength (lbs.)</th>
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</thead>
<tbody>
<tr>
<td>Ordinary cast iron</td>
<td>18,556</td>
</tr>
<tr>
<td>Swedish cast iron</td>
<td>33,000</td>
</tr>
<tr>
<td>Bessemer iron, mean of 5 trials</td>
<td>41,242</td>
</tr>
<tr>
<td>Wrought Iron Plates; mean breaking weight with, and across, the fibre.</td>
<td></td>
</tr>
<tr>
<td>Yorkshire plates; best</td>
<td>59,584</td>
</tr>
<tr>
<td>Derbyshire ordinary</td>
<td>54,556</td>
</tr>
<tr>
<td>Shropshire</td>
<td>45,130</td>
</tr>
<tr>
<td>Staffordshire</td>
<td>50,176</td>
</tr>
<tr>
<td>Mean of 4 trials of soft iron plates made by the Bessemer process</td>
<td>68,930</td>
</tr>
<tr>
<td>Boiler plates, made of very soft cast steel, (approaching in quality to iron,) made by the Bessemer process</td>
<td>110,000</td>
</tr>
<tr>
<td>Iron bars, hammered or rolled</td>
<td></td>
</tr>
<tr>
<td>English bar iron</td>
<td>55,572</td>
</tr>
<tr>
<td>Swedish</td>
<td>56,000</td>
</tr>
<tr>
<td>Bessemer iron, mean of 8 trials</td>
<td>72,064</td>
</tr>
<tr>
<td>maximum</td>
<td>82,110</td>
</tr>
<tr>
<td>Cast steel made by the Bessemer process, in its unhammered state; mean of 8 trials</td>
<td>63,092</td>
</tr>
<tr>
<td>Sheffield cast steel</td>
<td>130,000</td>
</tr>
<tr>
<td>Cast steel, made by &quot;Krupp&quot; of Essex</td>
<td>127,320</td>
</tr>
<tr>
<td>Captain Uchatus</td>
<td>91,955</td>
</tr>
<tr>
<td>Cast steel, made of Nova Scotia iron by the ordinary process</td>
<td>128,843</td>
</tr>
<tr>
<td>Bessemer steel, mean of 7 trials</td>
<td>152,911</td>
</tr>
<tr>
<td>maximum</td>
<td>162,770</td>
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STONE, ARTIFICIAL. Mr. Buckwell proposes the following plans for the construction of artificial stone. Taking fragments of stone sufficiently large to go freely into his...
STONE, ARTIFICIAL.

mould, he fills up the interstices with stones of various sizes, and then pours in a mixture of chalk and Thames mud or Mersey mud burnt together. This cement being poured into the mould, the whole is rammed together by falling hammers, and as the mould is perforated, the water is forced out, and the resulting stone is so hard, when removed from the mould, that it rings when struck. It will be evident to those acquainted with hydraulic mortars and the application of concrete, that this is only an improved concrete. The cost of production has been too great to admit of the general introduction of this artificial stone.

Ransome's patent siliceous stone, being one of the most successful attempts to produce a permanent stone artificially, requires a little further attention.

Mr. Ransome's attention was directed to the subject of artificial stone in 1844, while engaged as manager in the establishment of his relatives, the Messrs. Ransome, of the Orwell Works, Ipswich. At that time the above named firm happened to have a considerable order for flour mills for the colonies; and, from the difficulty experienced in reducing the French burn-stones, usually employed for the purpose, in situations where skilled labor was not attainable, it was proposed to obviate this difficulty by substituting for the stones surfaces of chilled cast iron. It was found, however, that after a while the grinding surfaces so constructed became glazed, and consequently unfit for the purpose for which they were intended.

While overlooking the proceedings of a workman engaged in renewing, on one occasion, the worn-out ridges on a burn-stone, Mr. Ransome was struck by the apparent absurdity of having to chip away not only the soft parts of the stone, but also the hard silicious prominences which constitute the real efficient portion of the surface. From the unequal and heterogeneous character of the burnstones usually employed, one side was apt to wear away sooner than the other; and to bring the grinding surface to any thing like a true bearing, the harder portions of the stone had to be cut away to the level of the lower and softer parts; thereby occasioning not only great labor in renewing the surface, but also a very rapid destruction of the whole material.

It at once occurred to Mr. Ransome, that if he could procure a stone of perfect homogeneous texture, the surface would wear down equally, and this objectionable system of levelling the whole to the depth of the softer and most worn parts would be completely obviated. Unfortunately, however, all natural stones were, from their very nature, of unequal texture, even within the limits of the small segments usually employed in the construction of mill-stones. Gathering up a handful of the chips struck off by the tools of the workmen, and pressing them together, the idea flashed across his mind that if he could discover any means of cementing these particles together, he would be able to produce a stone of nearly uniform hardness throughout. The most convenient material for this purpose that first suggested itself was plaster of Paris. This idea was immediately put into execution; and, although the results at first offered some slight prospect of success, a little subsequent experience showed the utter fallaciousness of the hopes he had entertained concerning them. But from the first moment that the scheme of cementing together the loose and disintegrated fragments of the mill-stone entered his mind, he comprehended by anticipation the whole of the results, which, after twelve years of assiduous application, he has succeeded in carrying to a triumphant conclusion.

After numerous failures, it occurred to Mr. Ransome that a solution of silica as a cementing material would be superior to any other, and he accordingly started on the inquiry after an easy method of producing a solution of flints. Experiment proved to the inventor that flints subjected to heat, under pressure in a boiler with a solution of soda or potash, were dissolved.

The accompanying illustration gives a sectional view of the apparatus employed in preparing the siliceous cement.

A is a steam-boiler, capable of generating a sufficiency of steam for heating the dissolving and evaporative vessels, and usually worked at a pressure of about 70 lbs. to the square inch. A is the upper lye-tank for dissolving the carbonate of soda. It is supplied with steam by the pipes 1, 2, 3, communicating with the boiler.

The first operation is to reduce the ordinary soda ash of commerce to the condition of caustic soda. For this purpose the ash is first dissolved in the tank n, the water in which is heated by means of the perforated steam-pipe 6. A quantity of quick lime is then added, and the mixture well stirred. The soda is by this means deprived of the carbonic acid which it contains, by the quick lime forming with it a carbonate of lime. To ascertain when the lye is quite caustic, a small portion is taken out in a test tube, and a few drops of hydrochloric acid added. If there is no effervescence, it may be assumed that the soda is entirely deprived of its carbonic acid, and is consequently caustic. When the lime, now converted into chalk, has subsided to the bottom of the tank, the clear supernatant lye is drawn off by the siphon 5, into the funnel 6, leading into a close vessel n, to prevent the carbonic acid of the air from entering in with it, and destroying its causticity. When the lye has been drawn off from n, the sediment remaining at the bottom of the tank is allowed to fall into the lower tank c, by withdrawing the plug a from the pipe b. Any undissolved crystals of the carbonate of soda which have been entangled among the particles of the lime are
now washed out and pumped back to the upper tank n, where it forms a portion of the next change.

The clear caustic being contained in the close tank n, has a further process of depuration to undergo before it is ready to be used as a solvent for the flints. The ordinary soda ash of commerce is always more or less adulterated with a sulphate of soda, which, although an inert substance in itself, if allowed to remain in the cement, subsequently makes its appearance in an ugly efflorescence on the surface of the finished stone. To get rid of the sulphate, the caustic solution of soda has added to it, in the tank n, a quantity of caustic baryta, obtained by burning the commercial carbonate of baryta with wood charcoal. The caustic baryta seizes upon the sulphuric acid contained in the sulphate of soda, and forms with it an insoluble sulphate of baryta, which is precipitated on the bottom of the tank. The depurated lye is then drawn off by the pipe d into the lower closed tank r, and the sulphate of baryta sediment passes off by the cock at the bottom. From r, the prepared solution of the caustic soda is pumped into the vertical boiler or digester v. This digester, in which the process of dissolving the flints is effected, is a cylindrical vessel, having a steam-jacket f, into which steam from the boiler a is supplied by the pipes 1, 2, 7. The inner cylinder r is provided with a wire basket c, reaching the whole length of the vessel, and serving to hold a collection of nodules of common flint. When r has been filled with the caustic lye, and the basket with flints, the manhole at the top is closed and well screwed down, so as to be able to resist a pressure of at least 60 lbs. on the square inch.- The cock at 7 is then opened, and the full pressure of steam from the boiler passes into the jacket f, and causes the lye in r to rise to the same temperature. The condensed steam in the jacket f returns to the boiler by the pipe 12, which it enters below the water line. The pressure maintained in the digester is generally about 80 lbs., and this is continued about 30 hours; at the end of which time the strength of the solution is tested. The workmen employed to superintend this part of the process generally use the tongue as the most delicate test. If the solution has a decidedly caustic alkaline taste, they conclude that there is still too much free soda in the cement, and the boiling is allowed to continue until the cement has a slightly sweetish taste, which occurs when the alkali has been nearly neutralized by combination with the silicate acid of the flints. A more scientific mode of testing the strength of the solution is to take a wine-glassful and drop a little hydrochloric acid into it; by this means the whole of the silicic in the solution is thrown down by the acid combining with the soda, so as to form chloride of sodium. The precipitated silicic presents an appearance resembling half-dissolved snow, and its comparative volume gives a good idea of the strength of the solution of the alkaline silicate. When it is judged that the alkali has taken up as much of the silicic as it is capable of doing, at the temperature to which it is subjected in the digester, the stop-cock 7, in the steam-pipe communicating with the jacket, is shut, and a cock in the pipe s is opened. The pressure of the steam in v then forces the fluid silicate through the pipe s into the vessel n,
STONE, ARTIFICIAL.

where it is allowed to stand for a short time to deposit any sediment which it may contain. From it is then conveyed by the pipe 9 to the evaporating pan k, which has a steam-jacket, k, supplied with steam by the pipe 10. The cement is then boiled in the evaporating pan until it becomes of the consistency of treacle, when it is taken out. The specific gravity of the cement, when ready for use, is about 1.600. The general proportions of the materials used in making up the artificial stone are about the following:

10 pints of sand, 1 pint of powdered flint, 1 pint of clay, and 1 pint of the alkaline solution of flint.

These ingredients are first well mixed in a pug-mill, and kneaded until they are thoroughly incorporated, and the whole mass becomes of a perfectly uniform consistency. When worked up with clean raw materials, the compound possesses a putty-like consistence, which can be moulded into any required form, and is capable of receiving very sharp and delicate impressions.

The peculiarity which distinguishes this from other artificial stones consists in the employment of silica both as the base and the combining material. Most of the varieties of artificial stone hitherto produced are compounds, of which lime, or its carbonate, or sulphate, forms the base; and in some instances they consist in part of organic matters as the cement, and having inorganic matters as the base.

To produce different kinds of artificial stone, adapted to the various purposes to which natural stones are usually applied, both the proportions and the character of the ingredients are varied as circumstances require. By using the coarser description of grits, grinding-stones of all kinds can be formed, and that with a uniformity of texture never met with in the bedbath stones. Any degree of hardness or porosity may also be given, by varying the quantity of silicate employed, and subjecting it to a greater or less degree of heat.

For some descriptions of goods a portion of clay is mixed with the sand and other ingredients, for the double purpose of enabling the material to stand up during the process of firing in the kiln, and to prevent its getting too much glazed on the surface.

The plastic nature of the compound allows of the most complex and undercast patterns being moulded with greater ease than by almost any other material we are acquainted with, if we except gutta percha, which, however, has the drawback of being affected by common temperatures.

The moulds employed are generally of plaster of Paris, and are so divided as to allow of the different pieces which cannot be withdrawn together being separately removed from the putty-like substance with which it has been filled. In filling the moulds the workmen use a short stick, with which they ram in the material, much in the way in which green sand is forced into contact with the pattern in an iron foundry, only with the difference, that the sand in this case is mixed with glutinous cement, which enables it to retain the form impressed upon it with much greater persistency and sharpness than is practicable with dry sand, or even loam. The casts, after being taken from the mould, are first washed over with a diluted mixture of the silicate, technically called "floating." The whole surface is then carefully examined, and any broken or rough portions are sleeved with a tool. It should have been mentioned that the plaster of Paris moulds, before being filled, are first painted over with oil and then dusted with finely-powdered glass, to prevent them adhering to the cast.

In attempting, however, to carry out his plan, two difficulties of a rather formidable character presented themselves. It was found that, in the process of desiccation, the surface of the stone parted with the moisture contained in the soluble silicate, and became hardened into a tough, impervious coating, which prevented the moisture escaping from the interior of the mass. Any attempt to dislodge the water retained in combination with the silicate in the interior of the stone, by raising the temperature of the whole above 212 degrees, had merely the effect of breaking this outer skin of desiccated silicate, and rendering the surface cracked and uneven.

Instead, therefore, of allowing the stones to be dried in an open kiln, they were placed in a closed chamber or boiler, surrounded with a steam-jacket, by which the temperature of the interior chamber could be regulated. In order that no superficial evaporation should take place, while the stones were being raised to the temperature of the steam in the jacket, a small jet of steam was allowed to flow into the chamber, and condense among and on the surface of the goods; until, as the temperature of the interior of the stones rose to 212° and upward, they became enveloped in an atmosphere of steam, which effectually prevented any hardening of the surface. The minute vents or spinnacles formed by the steam as it was generated in the interior of the masses, remained open, when the vapor contained in the closed chamber was allowed slowly to escape, and afforded a means of escape for any moisture which might still be retained among the particles of sand and cement. The whole of the moisture contained in the silicate of soda having been thus vaporized before it left the stone, an opportunity was afforded it by opening a communication with the external atmosphere, to pass off, leaving the interior of the stone perfectly dry. Simple as this arrangement may seem, we will venture to say that not one of our readers has hit upon the expedient through his own cogitations on the subject.
STONE, ARTIFICIAL.

The process, in effect, consists in stewing the stones in a closed vessel, and when all the moisture which they contain is converted into vapor, allowing it to escape, so that no one part of the mass can be dried before another. By this means Mr. Ransome was enabled to desiccate his artificial stone without any risk of the cracking or warping which had hitherto been the result of his attempts to harden them by exposure in an open stove.

After being thoroughly dried they are taken to the kiln; but, instead of being placed in saggers or boxes of clay, as is usually done in the potter's kiln, the goods are first bedded up with dry sand, to prevent any risk of their bending or losing their shape while burning. Flat slabs of fire-clay are then used to separate the various pieces laterally, and similar slabs are placed over them to form a shelf, on which another tier of goods is placed. The temperature of the kiln is very gradually raised for the first twenty-four hours; the intensity is then augmented, until at the end of forty-eight hours a bright red heat is attained, when the kiln is allowed to cool gradually for four or five days, when the goods are ready to be taken out.

The purposes to which this artificial stone is now applied are of the most miscellaneous description, comprising grindstones, whetstones for sharpening scythes, gothic foliage and mouldings for ecclesiastical decorations, tombstones and monumental tablets, chimney-pieces, fountains, garden stands for flowers, statuary, &c.

From being composed almost entirely of pure siliceous matter, it is not acted upon by acids, and is apparently quite insoluble, even in boiling water.

By proportioning the amount of cement, and varying the character of the sand which enters into the composition of the stone, it can be made porous or non-porous, as may be desired. The average absorbent power is less than that of the Bolsover Moor Dolomite used in the erection of the Houses of Parliament, and a little more than that of the Crag-leight Silexstone.

DIPPENHALL SILICA WORKS, FARNHAM, SURREY.

The manufactory which bears this name was built for the production of artificial stone, from a material only recently discovered, and never before employed for this purpose: soluble silica. This term is meant that kind of silica which is found to be readily dissolved by boiling in open vessels with solutions of caustic potash or soda; thus distinguished from the silica of flint, which is only soluble in such solutions at a temperature of about 300° Fahr. in a steam-tight boiler; and from that of quartz or sand, which is altogether insoluble. Up to the period when this discovery was made, silica had been only known to exist naturally in the two latter forms, and the former was merely a chemical product, derived from one of them by artificial means. This was at any rate the case in England; but it is right to state that a somewhat similar deposit was mentioned by M. Sauvage, a French chemist, before the researches were made to which this paper relates, as existing in the Département des Ardennes. This information, however, has not been turned to any practical account; and therefore a short history of the English discovery may not be uninteresting, as the latter has introduced to the world a new material applicable to a great variety of purposes.

About ten years ago the late Mr. Paine, of Farnham, proposed to the Chemical Committee of the Royal Agricultural Society of England that a complete analysis should be made of all the soils of the kingdom, for the purpose of ascertaining their value as natural manures. He undertook, for his own share, the strata of the chalk formation; and his thorough geological knowledge, aided by the chemical science of Professor Way, then consulting chemist to the Royal Agricultural Society, enabled him fully to complete the inquiry.

Some of the results of this joint investigation were communicated to the public by Messrs. Paine and Way, in the 12th volume of the Journal of the Royal Agricultural Society, in a paper entitled "On the Strata of the Chalk Formation." The soluble silica deposit is thus described:—"Immediately above the gault, with the upper member of which it sensibly intermingleth, lies a soft white-brown rock, having the appearance of a rich limestone. It is very remarkable on account of its low specific gravity, and still more so considering its position, by reason of the very small quantity of carbonate of lime which it contains. It is one of the richest subsoils of the whole chalk series, being admirably adapted for the growth of hops, wheat, beans, &c.

At the end of the paper it is remarked that a careful study of this rock may throw light upon the composition of soils.

The same authors contributed another article to the 14th volume of the "Journal," on "the Silica Strata of the Lower Chalk," in which they state that "when the former paper was published, they were not aware that this stratum contained a large proportion of silica in the form which chemists call "soluble" but that they wished, before making public their discovery, to ascertain whether it existed in sufficient quantity to render it available for agricultural use." They then detail the result of their researches during the intervening two years, as far as they concern agriculture, mentioning all the localities in which this stratum may be found in England, and the various ways of employing it beneficially as a manure. They allude to the fact that it will be found useful in its application to the arts, and conclude
STONE, PRESERVATION OF.

with these remarks on its probable formation:—"It is not insularof, for, with the exception of a few foraminifers, no traces of animal life can be observed in the rock by microscopic examination. It cannot have been subjected to heat of any intensity, or it would have been rendered insoluble in alkalis. It is plainly the result of aqueous decomposition; and it seems very reasonable to suppose that silicate of lime in solution derived from the older rocks may have met with carbonic acid produced either by vegetable and animal decay, or by volcanic agency, and at one and the same time carbonate of lime and gelatinous or soluble silica would have been formed. It should be remembered that we find these beds in immediate contact with the chalk; we find chalk without silica, silica without chalk, and, in other cases, both intimately blended. There is therefore good reason for supposing that these productions have been in some way connected."

While these investigations were going on, it was also found that the new material was useful in a variety of ways quite distinct from agriculture. Mr. Way's experiments led to the conviction that it would be serviceable in sugar-refining, in soap-making, in making animal charcoal, as a decolorizer, and above all, in the production of artificial stone.

The two investigators chiefly turned their attention to this latter branch of the subject; and in 1852 they took out a patent for "Improvements in the Manufacture of Burned and Fired Ware." In their specification they lay claim to the production of a superior class of burned goods by using the "soluble silica," with such admixtures of ordinary clay or lime as may be required. By these means they propose to make any kind of artificial stone, not at all resembling natural stone; blocks or slabs, excellent building bricks of any color, and good fire-bricks. They do not claim any novelty in moulding or burning, except that they consider that in some cases articles might be burned to a slight degree of hardness, then finished up by the use of tools, and afterward returned to any hardness that might be required.

Mr. Paine's many other duties for some time prevented his carrying this patent into effect; but at last, feeling it to be incumbent on him to make public so important a discovery, in spite of failing health and arduous occupation he commenced building the "Dippenhall Silica Factory" in 1856. Unhappily, he was not able to give his personal attention to the manufacture, so that it never had the benefit of his experience and scientific knowledge, and his death in 1858 put an end to his discoveries.

The factory has therefore been carried on from the first under serious disadvantages; but enough has been done to prove that its founder was not mistaken in the importance which he attributed to the invention. It is at present managed in a very simple manner. The material is carefully ground, either wet or dry, according to the purpose for which it is required, and mixed with clays or chalk when necessary. The bricks, vases, and other articles, are moulded in the ordinary way, and burned in round kilns. The building bricks, vases, and terra-cotta ware of all descriptions are generally acknowledged to be superior to any thing of the same kind hitherto produced, both in appearance, finish, and durability. There are at present practical difficulties in the manufacture of large blocks of stone, which do not seem to have been contemplated by the projectors; and the fire-bricks cannot yet be called superior to the Bourbridge manufacture, as was confidently expected. They are perfectly insensible under any amount of heat, but they are friable, and cannot bear a sudden change of temperature. Still, when it is remembered that the works have been carried on without any assistance from without, these difficulties only serve as incentives to further endeavors; and the present proprietor is convinced that all that is required to overcome them, and to raise the reputation of the "Dippenhall Silica Works" to the height to which their originator expected it to attain, is a man of equal scientific attainment, to resume the labors which were so prematurely arrested.—C. P.

STONE, PRESERVATION OF. The attention of the scientific world has for some time past been directed to the importance of providing a means for protecting the stone of our public buildings from the ravages of time and the injurious effects of the polluted atmospheres of our manufacturing and populous districts.

The principal cause of the ruinous decay which is so apparent in the national edifices, churches, mansions, &c., of this country, is generally admitted to be the absorption of water charged with carbonic or other acid gases, which by its chemical action either decomposes the lime or argillaceous matter forming the combining medium uniting the several siliceous or other particles of which the stone is composed, or mechanically disintigrates those particles by the alternate expansion and contraction caused by variations of temperature.

Many processes have from time to time been suggested, and several patents secured, for filling up the pores of the stone, and thus preventing the admission of those deleterious agents; but they have been mostly, if not entirely, composed of oleaginous or gummy substances or compounds, which, although possessing for a time certain preservative properties, become decomposed themselves upon exposure, and constantly require to be renewed; whilst from the nature of these applications the discoloration necessarily produced is highly objectionable.

A little reflection will be sufficient to satisfy a thoughtful mind, that in seeking for a
means of preserving the stone of our national buildings, &c., we ought not to rest satisfied simply with the application of any organic substances, however great may be their apparent preservative qualities for a time, but should endeavor to supply the defects of nature with an indestructible mineral incapable of change by any atmospheric influences.

The process of silicatization introduced by Kuhlmann has the disadvantage of requiring some considerable time before the atmosphere can do its work of effecting the necessary combination between the silica applied in solution to the stone, and the lime contained in it, and therefore, when it is applied to the external parts of any building, it is liable to be washed out before solidification has been secured. Mr. Frederick Ransome, advancing from his siliceous stone process a step further, meets the condition by effecting a chemical change at once within the stone. Mr. Ransome thus describes his process:

"Having been led to consider the importance of preserving the stone-work of our public and private edifices from the decay resulting from the variable condition of our climate, and other causes, I directed my attention to the existing processes proposed for effecting such an object, and more especially to that which has been for some time in use on the continent, in which a soluble silicate is employed, and I found that this process, though having for its base an important and indestructible a mineral as silica, was nevertheless very imperfect in its results. It appeared to me that one great cause of failure arose from the fact that the silicate, being applied in a soluble form, was liable to be removed from the surface by rain, or even the humidity of the atmosphere, before the alkali in the silicate could absorb sufficient carbonic acid to precipitate the silicate in an insoluble form. But another great and serious defect in this process still existed, viz., that even were it possible to effect the precipitation of the silicate, still it would be simply in the form of an impalpable powder, possessing no cohesive properties in itself, and therefore able to afford but little, if any, real protection to the stone. It seemed to me, therefore, necessary not only to adopt a process which should insure an insoluble precipitate being produced, independently of the partial and uncertain action of the atmosphere, but that, to render such means efficient, a much more tenacious substance than merely precipitated silica must be introduced; and in the course of my experiments I discovered that, by the application of a second solution, composed of chloride of calcium, a silicate of lime would be produced, possessing the strongest cohesive properties, and perfectly indestructible by atmospheric influences. The mode of operation is simply this:—The stone or other material of which a building may be composed, should be first cleaned by the removal of any extraneous matter on the surface, and then washed over with a solution of silicate of soda or potash, (the specific gravity of which may be raised to suit the nature of the stone or other material;) this should be followed by a solution of chloride of calcium, applied also with a brush; the lime immediately combines with the silica, forming silicate of lime in the pores of the stone; whilst the chloride combines with the soda, forming chloride of sodium, or common salt, which is removed at once by an excess of water. From the foregoing description it will be apparent that this invention has not only rendered the operation totally independent of any condition of the atmosphere in completing the process, but the work executed is unaffected by any weather, even the most excessive rains. Experience has shown, that where once applied to the stone, it is impossible to remove it, unless with the surface of the stone itself. I do not confine myself solely to the solutions above referred to; in some cases I prefer to use, first a solution of sulphate of alumina, and then a solution of caustic baryta, when a precipitate of sulphate of baryta and alumina is formed, the main object being to obtain two or more solutions, which upon being brought into contact mutually decompose each other and produce an indestructible mineral precipitate in the structure and upon the surface of the stone.

The application is one of extreme simplicity, and the material used perfectly indestructible. The rationale of the process is thus explained: A liquid will enter any porous body to saturation, whilst a solid cannot go any further than the first interstices next the surface. Take, then, two liquids capable of producing, by mutual decomposition, a solid, and by the introduction of these liquids into the cells of any porous body, a solid is produced by their mutual decomposition internally; ergo, if a solid could not go in as a solid, it cannot come out as a solid, and chemical decomposition having destroyed the solvents, they will never again be in a state of solution. The patience has secured to himself the application of this important principle, and whilst we name silicate of soda and chloride of calcium as the agent under mutual decomposition by contact for producing the chloride of sodium, and the imperishable silicate of lime, there are many other ingredients that are capable of producing like results.

STOVE. Spaces will not admit of our describing the Dutch or American stoves, which are mainly modifications of the ordinary forms, which are sufficiently well known. Pierce's pyro-pneumatic stove-grate, shown fig. 623, appears to meet the requirement of a stove, of an open fire, and good ventilation, in a remarkable manner.

In the annexed sketch is delineated the operation of the pyro-pneumatic stove, when employed in a large room, fig. 624. The channel c serves to supply pure air from any
source external to the building. The amount of the supply is regulated by the valve at n, and the direction of the currents is shown by the arrows. The fresh air is warmed in its course through the stove, and ascends to the ceiling, where it becomes diffused, and then descends, passing off by the smoke-flue. A special tube, n, is provided for ventilating the gas-lights, as exhibited in fig. 624.

The application of the pyro-pneumatic stove to the warming of churches is extremely simple, and its effects are found highly satisfactory. It gives an abundant supply of fresh
air, warmed to the desired temperature, and thereby prevents the influx of an impure atmosphere from vaults and other sources of pollution. It carries off the vitiated air by the smoke-flue, or in cases where a more rapid ventilation may be desirable, the warm air which it imparts to the air is sufficient to create an ample current in any shaft or ventilator that may be provided in the roof or spire of the building.

In all cases this apparatus is economical in a high degree, not only from the smallness of its first cost, but also from the fact that the full effect of the fuel consumed in it is secured to the uses of warming and ventilation. One element of economy cannot be too strongly insisted upon, viz., the feeling of warmth and comfort (even if it only exist in the imagination) which is communicated by seeing the glow and blaze of an open fire.

It would, perhaps, be no exaggeration to say, that with close stoves, heating apparatus, and other arrangements, in which there is no appearance of warmth, a much higher temperature of the atmosphere is required to make it even feel as warm as in that of an apartment heated by an open fire. Indeed, it may be fairly asserted that most persons will tolerate inconvenience and submit to expense, provided they see the cheerful blaze of the open fire, which they are at liberty to approach at will, and in the ever-varying embers of which they can conjure up visions of the past and fancies of the future.

One of the large pyro-pneumatic stove-grates, when in full operation, is found to be capable of heating an apartment containing 50,000 cubic feet of air. In a very large church, containing upward of 175,000 cubic feet of air, and capable of accommodating a congregation of 1,300 persons, four of these stoves of moderate size, arranged in convenient positions toward the angles of the building, so that every individual of the congregation may see the fire, are found to be sufficient in the coldest weather, and do not even require to be sustained in full action, except during a few hours in the morning. One of these stove-grates placed in the hall or lower part of a staircase, warms and tempers the internal climate of a large house, and gives the whole building a plentiful supply of pure fresh air. One of the smaller grates is capable of warming a large room. And whether in dwelling-houses, schools, churches, or apartments, the arrangements can readily be brought into operation at a moderate cost, and without any (beyond the most trilling) interference with existing structural arrangements.

The same inventor has introduced what he calls the fresh air fire-lump stove-grate, which may be thus described:—This grate is formed of the purest and best fire-clay, moulded in suitable forms, adapted to the varied arrangements that are found necessary, and consists of the open fire-grate bars in front, surrounded at the sides and back by the fire-clay lumps, around which humps an air-chamber is formed, communicating with the external atmosphere, admitting air to a cavity in the lower part of the grate, which communicates with the mouths of the vertical channels in the earthen lumps that surround the fire. The warm air which is communicated to the air through the body of these lumps, and which, from their small conducting power, rarely exceeds 90°, and can never be excessive, causes it to ascend through openings in the upper part of the casing into the apartment; its place being supplied by fresh admissions of air from below. The warm air thus admitted into the apartment floats above, and gradually descends as it cools, its place being supplied by warmer air from the stove-grate, and taking with it to the fire all the impurities of respiration, which is carried away by the flux, in which the heat maintains a constant upward current. Valves are provided for regulating the quantity and temperature of the fresh air admitted, and its distribution into the apartment when warmed.

STRUVE'S MINE VENTILATOR. The striking novelty of this ventilator is the gigantic scale upon which it has been constructed. Although in principle a pump of the simplest form, some of the pistons have been made 20 feet in diameter, and two pumps are about being constructed 21 feet in diameter. See fig. 625.

In some mines to which the machine has been applied, the rarefaction and ventilation have proved so strong as to prevent single doors being opened, unless protected by supplemental doors. The circumstance of the air not being compressed in the machine, admits of large valve spaces, so that there is scarcely any appreciable resistance to the passage of the air through the machine.

The annexed drawing, fig. 625, represents the machine in operation at the Governor and Company's large collieries at Own Avon, Glamorganshire; and the following list of licences granted to several large colliery proprietors, is a convincing proof that this invention ranks high among the modern improvements of mining.

The sectional view explains the internal construction, the darts showing the air-currents ascending the upper pit a, from the interior of the mine into the machine.

The piston is shown immersed in water, which forms an airtight packing.

The front or outlet valves k are shown in the external view of the ventilator. The end of the machine is represented open in the drawing, for the convenience of showing the inlet valves e, and of explaining the internal construction.
STRYCHNINE.

The air-ports, or valve-work, can be made three-fourths of the area of the pistons, thus reducing the resistance of the air-current through the machine to a minimum.

These machines can be applied to winding shafts.

Cost of machines about £200, for capacities of 10,000 cubic feet of air per minute.

STRYCHNINE. \(\text{C}_4\text{H}_11\text{O}_4\). The bitter poisonous principle contained in the different varieties of strychnos. It is usually extracted for commercial purposes from the nux vomica bean, the seed of the \(S.\) \text{nux vomica}. It is a well-marked alkali, and yields a great number of crystalline salts with acids and metallic chlorides. Its true constitution has been fully made out by the researches of Messrs. Nicholson and Abel. Although a most valuable medicine in paralytic affections, when employed in very small doses, it is a dangerous remedy in unskilful hands, and has been the cause of numerous deaths arising from carelessness, without reckoning the many who have been destroyed by it at the hands of the poisoner. Some years ago a panic was occasioned by a rumor of its employment for the purpose of giving a bitter flavor to beer; this has been shown to be incorrect. Still the quantities of it produced annually by various manufacturers could not fail to excite attention and uneasiness. As much as 1,000 ounces have been known to be purchased at one time. It has been proved, however, that the chief use is for the destruction of wild animals in Australia and other thinly peopled localities. A great number of processes have been devised for its preparation, but, after having been subjected to the extractive operations, the bean is generally found almost as bitter as before, indicating a want of economy in the methods. Probably the best method of extraction would be to disintegrate the beans with strong sul-
SUGAR.

Phloric acid, (which is without action on strychnine,) and then, after the addition of excess of alkali, to dissolve the base with benzole or chloroform. The latter being distilled off would leave the strychnine nearly pure, and only requiring crystallization. It has been shown by John Williams, that one bean will by this process yield a considerable quantity of crystals of pure strychnine.

The detection of strychnine has unhappily become a problem of only too frequent occurrence in chemical laboratories. It is, therefore, most important that ready and accurate methods should be known for the purpose. The following process may be relied on; it is founded on that adopted by Graham and Hofmann for the detection of it when present in beer. The stomach or other organic substance is to be cut small and boiled with dilute hydrochloric acid for a quarter of an hour. The acid fluid, after filtration, is to be carefully neutralized with potash, and then digested with recently ignited ivory black. The charcoal is to be separated by filtration, and, when well drained, is to be boiled with spirit of wine. The strychnine which will have been absorbed by the charcoal will be dissolved out by the spirit. The latter is then to be distilled off on the water bath. The contents of the retort, being transferred to an evaporating basin, are to be exposed on the water bath until dry. The residue is then to be tasted; if bitter, the process may be completed, but if no bitterness is observed it is scarcely worth while to proceed, as the merest trace of strychnine is capable of exciting the sense of extreme bitterness. The residue is to have a slight excess of potash added, and is to be shaken up with chloroform. The chloroform being separated is to be evaporated off. The operation must be repeated if the product be colored. The substance thus obtained is to have a little strong oil of vitriol added, and a piece of bichromate of potash is to be rubbed on the parts where the strychnine is supposed to be; if present, rich deep purple streaks will become evident.—C. G. W.

**SUGAR.** The following will show the composition of the various sugars, and their principal combinations with bases:—

<table>
<thead>
<tr>
<th>Sugar</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane sugar, or sucrose</td>
<td>C(<em>6)H(</em>{12})O(_6)</td>
</tr>
<tr>
<td>Grape or starch sugar, or glucose</td>
<td>C(<em>6)H(</em>{12})O(_6)</td>
</tr>
<tr>
<td>Fruit sugar, or fructose</td>
<td>C(<em>6)H(</em>{12})O(_6)</td>
</tr>
<tr>
<td>Milk sugar, or lactose</td>
<td>C(<em>6)H(</em>{12})O(_6)</td>
</tr>
<tr>
<td>Manna sugar, or mellitose</td>
<td>C(<em>4)H(</em>{12})O(_6)</td>
</tr>
</tbody>
</table>

**Compounds of cane sugar called sugarates.**

- With soda: Na\(_2\)C\(_6\)H\(_{12}\)O\(_6\)
- With potash: K\(_2\)C\(_6\)H\(_{12}\)O\(_6\)
- With lime: Ca\(_2\)C\(_6\)H\(_{12}\)O\(_6\)
- With baryta: Ba\(_2\)C\(_6\)H\(_{12}\)O\(_6\)
- With lead: Pb\(_2\)C\(_6\)H\(_{12}\)O\(_6\)
- With common salt: Na\(_2\)C\(_6\)H\(_{12}\)O\(_6\)

**Compounds of grape sugar, or glucose.**

- With baryta: Pb\(_2\)C\(_6\)H\(_{12}\)O\(_6\), or 3BaO, C\(_6\)H\(_{12}\)O\(_6\)
- With lime: Ca\(_2\)C\(_6\)H\(_{12}\)O\(_6\), or 3CaO, C\(_6\)H\(_{12}\)O\(_6\)
- With lead: Pb\(_2\)C\(_6\)H\(_{12}\)O\(_6\), or 6PoO, C\(_6\)H\(_{12}\)O\(_6\)

Cane sugar is soluble in all proportions in boiling water, and in \(\frac{1}{2}\) of cold.

It is sparingly soluble in alcohol of 70 per cent, and insoluble in absolute alcohol. The following Table, by Payen, shows the quantity of sugar contained in saccharine solutions of various specific gravity at 59° F.:—

<table>
<thead>
<tr>
<th>Parts of sugar</th>
<th>Parts of water</th>
<th>Specific gravity</th>
<th>Parts of sugar</th>
<th>Parts of water</th>
<th>Specific gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 dissolved in 50 give a syrup of 1.245</td>
<td>100 dissolved in 250 give a syrup of 1.147</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 60 = 1.222</td>
<td>100 = 50 = 1.111</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 70 = 1.277</td>
<td>100 = 45 = 1.089</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 80 = 1.281</td>
<td>100 = 50 = 1.074</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 90 = 1.266</td>
<td>100 = 60 = 1.063</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 100 = 1.257</td>
<td>100 = 75 = 1.055</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 120 = 1.222</td>
<td>100 = 90 = 1.045</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 140 = 1.200</td>
<td>100 = 110 = 1.050</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 160 = 1.187</td>
<td>100 = 115 = 1.046</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 180 = 1.176</td>
<td>100 = 145 = 1.022</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 200 = 1.170</td>
<td>100 = 244 = 1.018</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 = 245 = 1.015</td>
<td>100 = 2945 = 1.015</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The annexed Table, constructed by Neumann for the normal temperature of 63°, with the same object, is also submitted:—

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>1.0000</td>
<td>45</td>
<td>52</td>
<td>1.2209</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>96</td>
<td>1.0053</td>
<td>49</td>
<td>54</td>
<td>1.2265</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>92</td>
<td>1.0097</td>
<td>51</td>
<td>59</td>
<td>1.2374</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>87</td>
<td>1.0104</td>
<td>51</td>
<td>49</td>
<td>1.2373</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>52</td>
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<td>1.2481</td>
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</tr>
<tr>
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<td>1.0157</td>
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<td>47</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>54</td>
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<td>1.2545</td>
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</tr>
<tr>
<td>7</td>
<td>90</td>
<td>1.0154</td>
<td>54</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>92</td>
<td>1.0151</td>
<td>55</td>
<td>43</td>
<td>1.2602</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>91</td>
<td>1.0152</td>
<td>57</td>
<td>41</td>
<td>1.2625</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>1.0167</td>
<td>58</td>
<td>42</td>
<td>1.2710</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>90</td>
<td>1.0169</td>
<td>59</td>
<td>41</td>
<td>1.2725</td>
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<td></td>
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</tr>
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The specific gravity of crystallized cane sugar is 1.564. Crystallized cane sugar seems to be the most complete type of sugar known. Its crystals are the largest and most regular, and its taste the sweetest. These crystals are rhomboidal prisms, and appear largest in the form of sugar candy. When boiled much or heated with acids it would appear that a lower form of sugar resulted, namely, grape-sugar. This sugar crystallizes with difficulty in tufts or small needles. When the same treatment is further continued the power of crystallize is entirely lost. It has been attempted, but without success, to reverse these processes. The solution of this problem would be of great value to the world, and already much time and talent have been expended upon it.

At 300° sugar loses 0.6 per cent., and remains uninjured after seven hours; it melts at 320°, and at this point it seems to have lost some of its sweetness, and probably a portion of water. The same result is obtained at a lower temperature if more time is allowed. The color is changed to an orange-yellow at 410°; the sugar loses three equivalents of water, becomes gradually brown, has an empyreumatic taste, and is called caramel. With a heat approaching to a red heat, carburetted hydrogen, carbonic acid, acetic acid, and empyreumatic oils are produced, and carbon remains, amounting to 25 per cent. of the original mass. This disengagement of gases occurs with immense enlargement of volume, so that the carbonaceous residue is rendered exceedingly porous. If these gaseous products are inflamed, which may be done at 500°, the amount of heat disengaged is very great. It is believed generally that a perfectly pure solution of cane sugar in water will not decompose; this certainly is found to be the case in very dense solutions, at least after the lapse of several years; but when weak solutions are used, decomposition is effected in the course of a few months, even though the sugar is pure, the water distilled, and the vessel remain unpolished.

Solutions of sugar are readily decomposed by acids as well as by acid salts of every kind. They are decomposed also almost as readily by caustic alkaline solutions, and by hot solutions, of the carbonated fixed alkalies. Under the name alkaline solutions must be included both baryta and lime, if heat is to be long used; but both of these substances form compounds with sugar, the first of which will be treated of when beet-root sugar is under consideration. The compound of sugar and lime is very soluble in cold water, but is precipitated on heating. The amount dissolved is shown to be a true equivalent, by the inquiries of Peligot, who has proposed an ingenious method of ascertaining the amount of sugar in a solution by the estimation of the lime which it will dissolve. The lime in this process is estimated alkaliometrically by means of an acid. The Table on the following page has been constructed by M. Peligot for calculating the results.

Sugar has the capacity of reducing many of the higher to lower oxides, and also of entirely reducing the oxides of some of the metals. At the same time it effects the oxidation of some of the commoner metals, and keeps the oxides in solution. As an example of these actions, the hydrated peroxide of iron is reduced to protoxide, and retained in solution, whilst the hydrated oxide of copper is reduced to the suboxide and precipitated in solutions both of grape-sugar and uncrystallizable sugar. This action has been proposed as a mode of estimating the proportion of grape and uncrystallizable sugar in saccharine solutions, as will be shown. Iron is readily acted upon by grape and uncrystallizable sugar, and is retained in solution by sugar of every kind. Neither iron, zinc, nor lead is thrown down from sugar solutions by the usual alkaline reagents, but sulphide of ammonium separates them entirely.
SUGAR.

| Quantity of sugar dissolved in 100 parts of water | Density of syrup | Density of syrup when saturated with lime | 100 parts of residue dried at 120° contain
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<td>420</td>
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<td>1:179</td>
<td>Lime: 21:0, Sugar: 79:0</td>
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<tr>
<td>535</td>
<td>1:116</td>
<td>1:175</td>
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<td>1:106</td>
<td>1:148</td>
<td>19:9, 80:1</td>
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<td>520</td>
<td>1:106</td>
<td>1:148</td>
<td>15:3, 86:2</td>
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</table>

Saccharimetry.—We now come to the estimation of sugar, which is most simply performed by the hydrometer, when the solutions are pure and the kind of sugar known. But commercially it is required to ascertain the proportions of cane sugar, uncrystallizable sugar, water and impurities, and this is accomplished most successfully by means of the polarizing saccharometer proposed by Biot and improved by Soleil. The following is a description of this beautiful instrument:—Two tubular parts, $t$ and $t'$, figs. 627 and 628, constitute the principal part of the saccharometer. The light enters $n$, through a Nicol's prism $q$, shown separately, fig. 627, at $o$, and passes first an achromatic polarizing prism $p$, and shown separately at $p'$ and afterwards through a plate of quartz of double rotation at $p''$, which is also shown at $q$. This plate is composed of two semi-discs cut perpendicularly to the axis of crystallization; but, though exactly of equal thickness and equal rotating power, the one turns the ray to the right, while the other turns it to the left. At $p''$, the ray passes a plate of quartz of single rotation, and at $l$, two wedges of quartz endued with the power of rotation, but in a contrary direction to the preceding plate. These two wedges are again represented in $a$, and are so made that by turning the milled head $n$, the sum of their thickness can be increased or diminished at pleasure, while the amount of thickness is shown by the ivory graduated scale $e$, and vernier $v'$. Finally the ray traverses an analyzing prism $o$, and an eye-piece $l$. If the instrument is directed to the light the observer will see a
luminous disc, bisected by a central line (produced by the junction of the two semi-discs of quartz) of exactly the same tint, but which tint may be varied at pleasure, by rotating the Nicol's prism $n$, by means of the milled head $b$. If, however, we interpose between $p$ and $p'$, the tube $e$, fig. 627, filled with a solution of cane sugar, and the ends closed with glass, the semi-discs will be differently colored. Cane sugar, possessing the power of circular polarization, combines with the rotating power of the half disc which turns the ray to the right, but tends to neutralize the half disc, whose direction is the reverse. By increasing or diminishing the thickness of the wedges of quartz $l l'$, to the extent required for counteracting their rotation to the right, and causing the semi-discs to reassume the same colors, we have a means by the graduated scale $e$, $v' v'$, of measuring the rotating power, which is exactly proportional to the amount of cane sugar, temperatures being equal, and no foreign substance having the power of circular polarization being present.

To apply this method, the deviation must be known which is produced by a solution of sugar of known strength. For this purpose a given weight, $c$, of sugar is dissolved in such a quantity of distilled water that the solution occupies a given volume, $V$. Sufficient of this solution is taken to fill a tube of a certain length, and the deviation suffered by the plane of polarization of the luminous ray passing through this tube is measured. Let this deviation be $a$. Let then other quantities of sugar be dissolved in sufficient water to give the same volume of solution, $V$; and let the deviations produced by these solutions in the same tube be $a' a'' a'''$, &c.; then the quantities of sugar contained in the volume, $V$, of these liquids will be represented by the products $a$ $a' a'' a'''$, &c., respectively. If the sugar examined, instead of being pure, is mixed with other but inactive substances, it is evident that these same products express the absolute weights of pure sugar contained in the weights of substances employed in the formation of the liquids of the given volume, $V$. It is possible to employ proof tubes of different lengths; but it is then necessary to reduce by calculation the observed deflections to those which would have been produced in the same tube.

It often happens that solutions of sugar which have to be examined are turbid or strongly colored. When this interferes with the examination, they must be clarified and rendered either quite colorless, or when this is not possible the color must be at least reduced. This is often effected by precipitating the coloring matter of the syrups with sublurate of lead; but the most accurate method is by a filter of animal charcoal. The filtrates are then examined. When syrups contain, besides cane sugar, other constituents which exert an action upon the plane of polarization, the amount of cane sugar present may be determined by inverting, by means of hydrochloric acid, the rotary power of the cane sugar. No other saccharine substance is, in fact, known which suffers a similar change under the same circumstances.

If, for instance, the liquid under examination contains besides cane sugar, glucose, whose rotary action on the plane of polarization is in the same direction as that of cane sugar; if $a$ be the deviation observed to be produced by the liquid, then $a$ is evidently the sum of the separate deflections of the cane sugar $x$, and of the glucose $y$. About one-tenth of its volume of hydrochloric acid is added to the syrup, and it is kept for ten minutes at a temperature of 110°-114°. The cane sugar is thereby completely transformed into noncrystallizable sugar, which turns the plane of polarization to the left, while the rotary power of the glucose undergoes no alteration. When this change has been effected, the new deviation, $a'$, of the liquid is observed. It is now the difference between the deviation $y$ of the glucose and that of the noncrystallizable sugar derived from the cane sugar. But the degree of dilution of the liquid having been changed by the addition of the hydrochloric acid, the deviation observed, $a''$, must be replaced by the deviation, $\frac{10}{9} a''$, which would have been observed if the inversion could have been produced without the addition of hydrochloric acid.
Admitting therefore that a quantity of cane sugar which effects a deviation, \( x \), gives rise to a quantity of noncrystallizable sugar which effects a deviation, \( r \), \( r \), we have—

Before the inversion, \( x + y = a' \).

After the inversion, \( y + r x = \frac{10}{9} a'' \).

From these two equations the quantities \( x \) and \( y \) may be determined. The coefficient of inversion, \( r \), is determined once for all by a special experiment performed upon pure cane sugar at the temperature at which the experiments have afterwards to be made. According to Biot, this coefficient is \( \frac{10}{9} \) for hydrochloric acid at a temperature of 71°.

The process is the same when the cane sugar is mixed with noncrystallizable sugar, turning the plane of polarization to the left. In this case the initial deviation, \( a' \), of the liquid is the difference between the deviation to the right, \( r \), of the cane sugar, and the deviation, \( z \), to the left of the noncrystallizable sugar. After treating with hydrochloric acid, the deviation, \( a'' \), is composed of the deviations of the original noncrystallizable sugar, and of that produced by the action of the hydrochloric acid. We then have—

Before inversion, \( x - z = a' \).

After inversion \( x + r x = \frac{10}{9} a'' \).

It is important, in examining optically noncrystallizable sugar, always to employ the same temperature, because a change of temperature materially affects the rotary power of this kind of sugar.

The table appended includes each degree of temperature from +10 to +35 centigrade, and for qualities increasing in hundredths, this range being found sufficient for all practical purposes either in Europe or the colonies.

To note the temperature at which the observation is made, a tube \( z \), fig. 627, provided with a vertical branch, is employed. In this branch a thermometer, \( t \), is placed.

The following are two examples of the use of the table:

1. A solution of a saccharine substance prepared in the normal proportions of weight and volume recommended, and giving before acidulation a notation on the left-hand part of the scale of 75 divisions.

2. Another liquor similarly prepared, giving before the inversion a notation on the left of 80 divisions.

The strength expressed the value of the inversion 54 divisions.

The strength of the two solutions will be found thus; for the first, by seeing what is the figure of the column representing 15°, which is the nearest to the sum of the inversion, 95 divisions; it will be observed that this figure is 95-5, and that it corresponds to quality 70, shown on the same horizontal line in the last column but one, \( A \); hence we conclude that the substance contained 70 per cent. of sugar.

As to the second solution, the figure nearest 54 is 53-6, in the column for the temperature of +20°, and the strength sought will be 40° on the same line in the column of qualities. Finally, we shall find, besides, in the last column, \( B \), of the table, the quantity in grammes and centigrammes of the sugar contained per litre in the solutions, which is 114 gr. 45 for the first, and 65 gr. 40 for the second.

Other methods for the estimation of sugar have been adopted. We have already described Peligot's method by means of lime. When sugar is formed from starch, its complete saccharification may be determined by the action of sulphuric acid; for, if on a strong solution of imperfectly formed grape sugar, nearly boiling hot, one drop of strong sulphuric acid be added, no perceptible change will ensue, but if the acid be dropped into solutions of either cane or perfectly formed grape sugar, black carbonaceous particles will make their appearance.

The black oxide of copper is not affected by being boiled in solution of starch sugar.

"If a solution of grape sugar," says Troumer, "and potash, be treated with a solution of sulphate of copper, till the separated hydrate is re-dissolved, a precipitate of red oxide will soon take place, at common temperatures, but it immediately forms if the mixture is heated. A liquid containing \( \frac{1}{10} \) parts of grape sugar, even one-millionth part," says he, "gives a perceptible tinge (orange) if the light is let fall upon it." To obtain such an exact result, very great nicety must be used in the dose of alkali, which is found extremely difficult to hit. With a regulated alkaline mixture, however, an exceedingly small portion of starch sugar is readily detected, even when mixed with Moscovado sugar.
SUGAR.

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SUGAR.
Fehling has reduced this to a quantitative test, and makes a solution of copper, that will keep permanently. This is seen by the following:

- 40 grammes of sulphate of copper,
- 160 grammes of neutral tartrate of potassa, or 200 grammes of tartrate of soda,

dissolved and added to 700—800 cub. c. (grammes) of caustic soda, specific gravity 1·12.

This is diluted with water to 1154·5 cub. c.

Of this solution 1 cub. c. = 0·0050 grape sugar, or 0·00475 cane sugar.

Grains may be used instead of grammes, and then 1 grain = 0·0050 grape sugar, without change of calculation.

100 parts of grape sugar, 95 cane sugar, 90 starch,

Urine may be tested with this. It should be first diluted 10 to 20 times with water; when the test is added, it should be boiled a few seconds, when the suboxide of copper falls. Very constant results may be obtained.

Caramelin is the name given by E. Maumene to a brown substance, insoluble in acids and alkales, which is produced by evaporating sugar with fifteen to thirty times its weight of chloride of tin, and heating it to about 220° Fahr. It is C\textsubscript{2}H\textsubscript{4}O\textsubscript{4}, and being constant has been proposed by him to be used as a test of the presence and quantity of sugar.

Horsley detects minute quantities of sugar by means of chromate of potash.

**SUGAR REFININGS.**—The raw or Muscovado sugar, as usually imported, is not in a state...
of sufficient purity for use. The sugar is blended with more or less of fruit and grape sugars, with sand and clay, with albuminous and coloring matter, chiefly caramel. To separate the pure sugar, the plan formerly adopted was to add blood, eggs, and lime-water to a solution of the raw sugar, and after applying heat, to remove the thick scum of coagulated albumen, which also removed a considerable portion of coloring matter. The clear liquid was concentrated, and the semi-crystalline mass being placed in conical moulds, as much of the molasses as would drain by gravitation was allowed to escape from the points of the moulds, and the remainder was expelled by allowing water or a solution of pure sugar to trickle through the mass of crystals. The loaves, being trimmed into shape and dried, were fit for sale.

By this process only a small proportion of the sugar was made into leaf. The method of removing the coloring matter was crude, imperfect, and expensive, and the high temperature requisite for the fermentation of the syrup not only injured its color, but converted a large proportion of the sugar into the uncrystallizable variety.

These defects were remedied, to a great extent, by the adoption of Howard's vacuum pan, for the concentration of syrups under diminished atmospheric pressure, and consequently at a low temperature, together with the use of filtering beds of animal charcoal for the removal of coloring matter.

There are three classes of sugar refineries in this country, the chief productions of which are respectively:

1st. Leaf sugar.
2d. Crystals, (i. e. large, well-formed, dry white crystals of sugar.)
3d. Crushed sugar.
In the former two, good West India, Havanna, Mauritius, or Java sugar are almost exclusively used. In the last, all classes of sugar are indiscriminately employed. The manufacture of loaf sugar is chiefly carried on in London; of crystals, in Bristol and Manchester; of crushed sugar, in Liverpool, Greenock, and Glasgow. Besides these places, which are the chief seats of the sugar-refining trades, this branch of industry is carried on more or less at Plymouth, Southampton, Goole, Sheffield, Newton, (Lancashire,) and Leith. The methods vary a little in different refineries, but the following description refers to the most modern and best conducted which are to be found in this country. The general arrangements of a sugar house are shown in figs. 629 and 630.

Loaf Sugar.—Solution. The raw sugar is emptied from the hogsheads, boxes, or mats, as the case may be, and discharged through a grating in the floor into a copper pan, about 8 feet in diameter. This dissolving pan is sometimes, although incorrectly, called a defecator; it was formerly called a blow-up, from the practice of blowing steam into it, but the practice and the name are now antiquated. Hot water is added, and the solution is facilitated by the action of an agitator, or stirrer, kept in motion by the steam-engine. The proportions of sugar and water are regulated so that the liquid attains a specific gravity of about 1.250 or 39° Baumé, as a higher density than this would interfere with subsequent processes. A copper coil or casing to the pan, heated by steam, furnishes the means of raising the liquid to a temperature of 165°. The plan of boiling the ‘liquid’ is becoming gradually disused. If the solution is acid, sufficient lime-water is added to make it neutral. The use of blood, which was formerly added at this stage, is in most cases dispensed with; the advantage arising from its use is readily obtained from the employment of an increased amount of animal charcoal in a subsequent process, while the mischief arising from the introduction of nitrogenous matter so prone to decompose is avoided. Some machinery is used for crushing the hard lumps to facilitate solution.

Removal of insoluble matter.—The liquor having been brought to the requisite density and temperature, and also being perfectly neutral, is passed through the bag filter.

The apparatus consists of an upright square iron or copper case, a, a, fig. 631, about 6 or 8 feet high, furnished with doors; beneath is a cistern with a pipe for receiving and carrying off the filtered liquor; and above the case is another cistern c. Into the upper cistern the syrup is introduced, and passes thence into the mouths e, e, of the several filters, d, d. These consist each of a bag of thick twilled cotton cloth, about two feet in diameter, and 6 or 8 feet long, which is inserted into a narrow ‘sheath,’ or bottomless bag of canvas, about 5 inches in diameter, for the purpose of folding the filter-bag up into a small space, and thus enabling a great extent of filtering surfaces to be compressed into one box. The office of each compound bag is tied round a conical brass mouth-piece or nozzle e, which screws tight into a corresponding opening in the bottom of the upper cistern. From 40 to 400 bags are mounted in each filter case. The liquor which first passes is generally turbid, and must be pumped back into the upper cistern for refiltration. The interior of the case is furnished with a pipe for injecting steam, which is occasionally used for warming the case. Fig. 632 shows one mode of forming the funnel-shaped nozzles of the bags, in which they are fixed by a bayonet catch. Fig. 633 shows the same made fast by means of a screwed cap, which is more secure.

When the bags are foiled from the accumulation of clay and a slimy substance on their inner surfaces, the filter is unpacked, the bags withdrawn from the sheaths, and well washed in hot water. This washing is usually performed with a dash-wheel, or some one of the numerous kinds of washing-machines now in use. Perhaps that of Manlove & Allport, of Nottingham, is in greatest favor. The dirty water, with the addition of a little lime, is smartly boiled, and after some hours being allowed for subsidence, the supernatant, clear, weak solution of sugar is removed and used in the first process, (solution,) while the muddy residue is placed in canvas bags and subjected to pressure. The residue, technically called scum, is thrown away.

Removal of color.—The liquor issuing from the bag-filters generally resembles in color dark sherry wine. To render this colorless, it is passed through deep filtering-beds of granulated burnt bones or animal charcoal. When this substance was first introduced, beds of a few inches in depth were considered sufficient, but the quantity of charcoal used per ton of sugar has steadily increased, and filters of no less a depth than 50 feet are now sometimes used.

Cylinders of wrought or cast iron, varying in diameter from 5 to 10 feet, and in height from 10 to 50, having a perforated false bottom, a couple of inches above the true one, are filled with granulated animal charcoal.
The grain varies from the size of a turnip seed to that of peas, some refiners preferring it fine, and others coarse.

Liquor from the bag filters is run on to the charcoal till the cylinder is perfectly filled, when the exit tap at the bottom is opened, and a stream of dense saccharine fluid, perfectly colorless, issues forth. The amount of sugar which the charcoal will decolor depends upon the age and composition of the charcoal, the degree of perfection with which the previous revivification has been performed, and the quality, color, and density of the liquor to be operated upon. One ton of charcoal is sometimes used to purify two tons of sugar; and in at least one refinery, where inferior sugar is operated on, two tons of charcoal serve for one ton of sugar. In most provincial refineries about one ton of charcoal is used to one of sugar; but in London, from the dearness of fuel and other causes, a smaller proportion of charcoal is employed. The liquor from the charcoal filter, at first colorless, becomes slightly tinged, and in course of time, varying from 24 hours to 72, the power of the charcoal becomes exhausted, the partially decolored syrup is passed through a fresh charcoal filter, and the sugar is washed out from the charcoal by means of hot water. The charcoal is ready to be removed for revivification, which process is treated of farther on.

Concentration.—The next process in sugar-refining is the evaporation of the clarified syrup to the granulating or crystallizing point. The more rapidly this is effected, and the less the heat to which it is subjected, the better and greater is the product in sugar-loaves. No apparatus answers the refiner's double purpose of safety and expedition as well as the vacuum-pan.

The vacuum-pan, invented by Howard, and patented in the year 1813, is an enclosed copper vessel, heated by steam, passing through one or more copper coils, and a steam-jacket. The vapor arising from the boiling solution of sugar is condensed by an injection of cold water, the arrangement of which, and the maintenance of a vacuum, closely resemble the condenser, injection, and air-pump of an ordinary condensing steam-engine.

Fig. 634 shows the structure of a single vacuum-pan. The horizontal diameter of the copper spheroid $C$ is from 7 to 10 feet; the depth of the under hemisphere $A$ is at least 2 feet from the level of the flange; and the height of the dome-cover is from 3 to 5 feet. The two hemispheres (of which the inferior one is double, or has a steam-jacket) are put together by bolts and screws, to preserve the joints tight against atmospheric pressure.

The steam enters through the valve $V$, traversing the copper coil $N$, and filling the steam-jacket, the condensed water issuing from a small pipe below. $C$ represents the dome of the vacuum-pan, the vapor from which passing in the direction of $A$, allows any previous sugar carried over by the violence of the ebullition to be deposited in the receiver $M$. 
The vapor is condensed by jets of cold water issuing from a perforated pipe, and the water, uncondensed vapor, and air are removed by the action of a powerful air-pump. 1 is the measure cistern, from which the successive charges are admitted into the pan; 1 and x represent respectively a thermometer and a barometer, the former being required to indicate the temperature of the boiling syrup, and the latter the diminished atmospheric pressure within the pan. 1 is the discharge-cock, and n, the proof-stick, is an apparatus inserted air-tight into the cover of the vacuum-pan, and which dips down into the syrup, serving to take out a sample of it, without allowing air to enter. It is shown in detail by fig. 639, which represents a cylindrical rod, capable of being screwed air-tight into the pan in an oblique direction downward. The upper or exterior end is open; the under, which dips into the syrup, is closed, and has on one side a slit a (figs. 636, 639), or notch, about \( \frac{1}{2} \) in. wide. In this external tube there is another shorter tube b, capable of moving round it, through an area of 180°. An opening upon the under end c corresponds with the slit in the outer tube, so that both may be made to coincide, fig. 635, a. A plug d is put in the interior tube, but so as not to shut it entirely. Upon the upper end there is a projection or pin, which catches in a slit of the inner tube, by which this may be turned round at pleasure. In the lower end of the plug there is a hole e, which can be placed in communication with the lateral openings in both tubes. Hence it is possible, when the plug and the inner tube are brought into the proper position, a, fig. 635, to fill the cavity of the rod with the syrup, and to take it out without allowing any air to enter. In order to facilitate the turning of the inner tube within the outer, there is a groove in the under part, into which a little grease may be introduced.

Whenever a proof has been taken, the plug must be placed in reference to the inner tube, as shown in fig. 635, c, and then turned into the position a; when the cavity of the plug will again be filled with syrup. c must be now turned back to the former position, whereby all intercourse with the vacuum-pan is cut off; the plug being drawn out a little, and placed out of communication with the inner tube. The plug is then turned into the position a, drawn out, and the proof examined by the fingers.

The method of using the vacuum-pan varies with the character of the grain required to be produced. On commencing boiling, the syrup should be run in as quickly as possible, till the whole heating surface is covered, when the steam is turned on, and the evaporation conducted at a temperature of from 170° to 180° Fahr. As soon as the syrup begins to granulate, the temperature becomes reduced to 160°; and finally, just before the evaporation is completed, and the sugar ready to be discharged into the heater, it is further reduced, and approaches 150°, being the lowest temperature at which proof sugar boils, 3 inches from a perfect vacuum. When the sugar-boiler ascents, by withdrawing a sample of the syrup by means of the proof-stick, and examining it against the light between his finger and thumb, that the crystals are in a sufficiently forward state for his purposes, he adds another measure full to that already in the pan, and the same process is repeated till the whole charge has been admitted. After each successive charge the crystals continue increasing in size to the end of the operation, those first formed acting as nuclei; a skip, as it is technically called, or a panful of the concentrated sugar, may be made in from two to four hours from the commencement of the boiling. If a fine grain sugar be required, greater quantities of syrup are admitted at each charge of the measure, and vice versa.

Making of loaf sugar.—The proof sugar, at a temperature not exceeding 145°, is then let down through a cock or valve in the bottom of the pan into the heater. The sugar liquor consists, at this stage of the process, of a large number of small crystals floating in a medium of syrup.

The heater is an open copper pan of about the same capacity as the vacuum-pan, and is furnished with a steam-jacket and provided with an agitator—in fact, it closely resembles the dissolving-pan used for the first process. The object to be attained in the heater is to raise the sugar to a temperature of 150°, which has been found by practice to be the point best adapted for hardening and completing the formation of the crystals, during which process the sugar is constantly stirred.

The sugar is then run out through a cock in the bottom of the heater into a hule, from whence it is poured into moulds or cones of sheet iron strongly painted. The sizes of the moulds vary, from a capacity of 10 pound loaves to that of 50 pound bastard—a kind of...
SUGAR.

soft brown sugar obtained by the concentration of the inferior syrups. These moulds have the orifices at their tops closed with nails inserted through pieces of cloth or india-rubber, and are set up in rows close to each other, in an apartment adjoining the heaters. Here they are left several hours, commonly the whole night, after being filled, till their contents become solid, and they are lifted next morning into an upper floor, kept at a temperature of about 100° by means of steam-pipes, and placed over gutters to receive the syrup drainings—the plugs being first removed, and a steel wire, called a piercer, being thrust up to clear away any concretion from the tip. The syrup which flows off spontaneously is called green syrup. It is kept separate. In the course of one or two days, when the drainage is nearly complete, some finely clarified syrup, made from a filtered solution of fine raw sugar, is poured to the depth of about an inch upon the base of each cone, the surface having being previously rendered level and solid by an iron tool, called a bottoming trowel. The liquor, in percolating downward, being already a saturated syrup, can dissolve none of the crystalline sugar, but only the colored matter and molasses; whereby, at each successive liquoring, the loaf becomes whiter, from the base to the apex.

To economize the quantity of "fine liquor" used, it is usual to give a first and even a second liquor of an inferior quality before applying the finishing liquor, which is a dense and almost saturated solution of fine sugar absolutely free from color. A few moulds, taken promiscuously, are put at intervals, or one at a time, to inspect the progress of the heated syrups, and when the loaves appear to have acquired as much color, according to the language of refiners, as is wanted for the particular market, they are removed from the moulds, turned on a lathe at the tips, if necessary, set for a short time upon their bases, to diffuse their moisture equally through them, and then transferred into a stove heated to 130° or 140° by steam pipes, where they are allowed to remain for two or three days, till they are baked thoroughly dry. They are then taken out of the stove, and put up in paper for sale.

In the above description of sugar-refining, nothing is said of the process of caking loaves, because it is now nearly abandoned in all well-appointed sugar-houses.

The drainage of the last portion of the liquor from the moulds is sometimes accelerated by means of a vacuum. Centrifugal action has been also proposed for this purpose, but has not been found to succeed.

The drainings from the moulds which are collected in gutters and run into cisterns are boiled, and form an inferior quality of sugar. The drainings from this last sugar consist of treacle or syrup, which is always obtained as a final product.

Manufacture of crystals.—The use of centrifugal action for the separation of liquids and solids has been adopted in the arts for many years; its application for the separation of syrup and sugar occurred to several individuals, but it was best effected by means of the admirable hydro-extractor, invented and patented by Manlove & Alliott, of Nottingham. Various modifications of this machine have been proposed and patented, but it is very doubtful whether any thing that has been devised has improved upon the original machine. It would be tedious and unnecessary to detail the list of so-called improvements.

Considerable value, however, has been supposed to attach to the use of a blast of steam to free the meshes of the revolving cylinder from the semi-crystalline syrup. This plan was the subject of a patent granted to the late C. W. Finzel, but the opinion of those who consider that the injurious action of a blast of open steam upon the syrup far outweighs the advantage arising from a machine so easily cleansed, is gaining ground daily.

In the manufacture of "crystals," sometimes called centrifugal sugar, all the earlier processes previous to boiling are conducted as already described.

Concentration.—It is found more convenient to make use of vacuum-pans of large dimensions, and provided with extra heating surface by the introduction of several additional coils. The object sought to be obtained is the formation of large crystals, which is effected as follows:—The pan is partially filled with liquor; this is concentrated until minute crystals appear; a further portion of liquor is added—the concentration continued—more liquor and further concentration again and again—until the pan is filled; the object being to keep the mother-liquor sufficiently fluid to prevent the formation of a second crop of crystals, and yet sufficiently dense to feed the crystals already formed. One-half the contents of the pan is discharged into the heater, while the remaining half is retained as a nucleus, and the pan charged as before. This process is sometimes repeated several times.

Separation of crystals.—The semi-fluid mass is removed to the centrifugal machines with the least possible delay, and each machine barely attains its maximum speed before the syrup is discharged. To cleanse the surface of the crystals, they are washed with liquor, sprinkled in the machine by means of a watering-can, a few pints of liquor being used to each ewt.

By this process the percentage of sugar obtained from the first and each separate crystallization is considerably less than that obtained in the making of loaf-sugar or the ordinary method of making "crushed," though the total product does not vary materially, being rather more than that of the former where the product is stove-dried, and less than the latter, which is sold damp. The drainage is diluted, filtered through animal charcoal, boiled,
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and passed through the centrifugal machines, and results in a second quality of sugar, the crystals being smaller. The drainage from this is treated in a similar manner, and a third quality of crystals is the result. A fourth quality of crystals is also sometimes obtained, the drainage from which is again boiled and laid aside in large moulds to crystallize for about a week, when treacle and a low quality of "pieces" are the final result. The drainages are sometimes incompletely treated with inferior qualities of raw sugar.

The difficulty with which these large and beautiful crystals obtained by this process dissolve, is an obstacle to their extensive consumption.

Crushed sugar.—This process closely resembles the manufacture of loaf-sugar, but the raw sugar used is generally of an inferior quality. The filtration through the animal charcoal is in consequence not so perfect; the concentration resembles that of loaf-sugar, but the use of a heater is dispensed with, and the process of liquoring is also dispensed with where practicable. The first crystallization is called "crushed," and the second "pieces," the drainage from which goes by the name of "syrup." When this syrup is diluted, filtered through animal charcoal, and concentrated, it is called "golden syrup."

Treatment of molasses.—Foreign and colonial molasses, containing a large proportion of crystallizable sugar, are purchased by refiners. The Muscovado molasses from Cuba, from Porto Rico, Antigua, and Barbadoes, are esteemed the best, but the quality of molasses deteriorates as improvements in the manufacture of sugar are introduced on the plantations. The treatment of molasses formerly was simple; it was merely concentrated and allowed to stand for several weeks in large moulds to drain. The liquid was sold as treacle, and the impure soft, dark sugar, called bastard, found a market amongst the poorer classes, especially in Ireland.

The more recent and better plan is to dilute the molasses, filter it through animal charcoal, and concentrate to the crystallizing point, but without forming crystals. This readily crystallizes in the moulds, and in place of the bastards and treacle a bright yellow sugar and a fair quality of syrup are the result. Good molasses yields 40 per cent. sugar, 40 per cent. syrup, the remaining 20 per cent. being water, dirt, and loss.

Palm or Date Sugar.—Many trees of the palm tribe yield a copious supply of sweet juice, which, when boiled down, gives a dark brown deliquescent raw sugar, called in India jaggery. The wild date palm and the gonumuto palm yield the largest proportion of this kind of sugar, which is chemically identical with the sugar from the cane, though the crudeness of the manufacture is very injurious to it, and causes a large proportion to assume the uncrystallizable condition. One-twenty-fourth of all the cane sugar extracted for useful purposes is obtained from the palm-tree.

Beet-root Sugar.—The extraction of sugar from beet root, which has become an important manufacture in several countries on the continent, especially in France and Germany, was developed in consequence of the difficulty of obtaining colonial sugar in France during the blockade in the time of Napoleon I. The high price of sugar (65. per lb.) was not the only alluring motive; as a prize of a million of francs was offered by the Government for the most successful method of manufacturing indigenous sugar. The beet is a biennial plant, native to the south of Europe. There are several varieties of this root, each fitted to its own climate and soil; but the white Silisian beet is the most prized where it can be grown, on account of the large amount of sugar in the juice, and the comparative absence of tallow; it is less prone to decay when stored previous to use. The average composition of the root of the sugar beet may be stated as follows:

<table>
<thead>
<tr>
<th>Sugar</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gluten</td>
<td>8%</td>
</tr>
<tr>
<td>Woody fibre</td>
<td>5%</td>
</tr>
<tr>
<td>Water</td>
<td>81%</td>
</tr>
</tbody>
</table>

The proportion of sugar varies very much. First, it is greater in some varieties than others; second, it is greater in small beets than in large; third, in dry climates, especially when the climate is dry after the roots have begun to swell; fourth, in light than heavy soils; fifth, in the part above than under ground; sixth, when manure has not been directly applied to the crop. The average proportion of sugar extracted from beet is 6 per cent., though it is stated that 7% per cent. is obtained in some well-conducted manufactories. In France and Belgium the average yield is 14 or 15 tons of beet to the acre, while about Magdeburg they do not exceed 10 to 13 tons, but the latter are richer in sugar.

During the first year of its life the root is developed to its full size, and secretes the whole amount of sugar which, in the natural life of the plant, furnishes the material for the growth and maturity of its upper part. It follows that when the plant is cultivated for its sugar, the sugar manufacturer has little, if any, difficulty in the first year's stage of development is complete. The time required for this depends upon that of the sowing, and upon the season. Its criterion is the commencement of death in the leaves. When ripe the beet roots are dug out, the mould gently shaken off, and the heads cut off, together with as much of
the root as shows the presence of leaf buds. As the action of light is detrimental even to the exhumed roots, the latter must be covered quickly. If the quantity be small, they may be covered with the leaves which have been cut off. It is more usual, however, to pile them in heaps on the ground, to hinder the evaporation of their water, and to protect them from light and frost by covering the heaps with a thin layer of earth. These mounds are sometimes sprinkled with water, which is taken up by the roots restoring to them the plumpness and crispness which they have lost in a dry season.

Boussingault gave the following analyses of French beets:

<table>
<thead>
<tr>
<th>Where grown</th>
<th>Time of taking from ground, hr.</th>
<th>Per cent. of dry matter</th>
<th>Water</th>
<th>Sugar</th>
<th>Lignineous fibre and albumen</th>
<th>Fecula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botanic school</td>
<td>Aug. 2.—Roots small</td>
<td>9.5</td>
<td>90.5</td>
<td>59</td>
<td>4.5 added to the lip. matter.</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Sept. 1.—Root of 1100 grammes = 14 lb.</td>
<td>7.4</td>
<td>92.6</td>
<td>42</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sept. 1.—Root, 400 grammes = 1 lb. 24 oz.</td>
<td>9.4</td>
<td>90.5</td>
<td>59</td>
<td>2.8</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Sept. 7.—Root, 700 to 800 grammes</td>
<td>10.0</td>
<td>90.0</td>
<td>73</td>
<td>1.9</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Young root of 0'9 grammes = 4'8 grains</td>
<td>10.7</td>
<td>66.6</td>
<td>9.9</td>
<td>4.4</td>
<td>2'4</td>
</tr>
<tr>
<td>Garden of M. Brognaart</td>
<td>Sept. 23.—Root from 90 to 100 grammes = 2' 8 oz.</td>
<td>10.4</td>
<td>84.9</td>
<td>16.9</td>
<td>3.3</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Oct. 9.—Root, 150 grammes = about 1'5 oz.</td>
<td>10.8</td>
<td>81.2</td>
<td>12</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>Vigneux</td>
<td>Sept. 23.—Root, 500 grammes = 1' 9 lb.</td>
<td>10.9</td>
<td>83.1</td>
<td>11.9</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sept. 23.—Root, 700 grammes = 2' 7 lb.</td>
<td>10.9</td>
<td>81.9</td>
<td>8.6</td>
<td>2.7</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Aug. 1.—Root, 300 grammes = 3' 4 lb.</td>
<td>10.9</td>
<td>84.8</td>
<td>9.9</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aug. 11.—Root, 600 grammes = 3' 9 lb.</td>
<td>11.8</td>
<td>87.4</td>
<td>8.2</td>
<td>2.3</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Aug. 30.—Root, 1 kilogramme = 3' 5 lb.</td>
<td>12.1</td>
<td>88.9</td>
<td>5.6</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Beet in flower, 200 grammes = about 1'5 lb.</td>
<td>13.6</td>
<td>86.5</td>
<td>9.6</td>
<td>3.3</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Beet of two years in seed</td>
<td>15.6</td>
<td>84.5</td>
<td>6.0</td>
<td>2.5</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>White beet of Silesia</td>
<td>15.8</td>
<td>84.2</td>
<td>3.1</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaves of the beet —</td>
<td>16.4</td>
<td>90.5</td>
<td>8.5</td>
<td>3.6</td>
<td>-1.4</td>
</tr>
</tbody>
</table>

The beet-root rasp is represented in figs. 640, 641. a, a is the framework of the ma-

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elime; b the feed-plate, made of cast iron, divided by a ridge into two parts; c, the hollow drum; d, its shaft, upon either side of whose periphery nuts are screwed for securing the saw blades e, e, which are packed tight against each other by means of laths of wood; f is a pinion upon the shaft of the drum, into which the wheel g works, and which is keyed upon the shaft h; i is the driving rigger; k, pillar of support; l, blocks of wood, with which the workman pushes the beet-roosts against the revolving rasp; m, the chest for receiving the beet-pap; n, the wooden cover of the drum, lined with sheet iron. The drum should make 500 or 600 turns in the minute.

By the process of M. Schultzenbach, the manufacture may be carried on during the whole year, instead of during a few winter months. At Waghäusel, near Carlsruhe, this system is adopted. The beets having been washed, are rapidly cut up into small pieces, and subjected to the drying heat of a coke fire for six hours. They lose from 80 to 84 per cent. of their weight; the dried root may be kept without injury for many months, and the sugar is extracted by infusion. At this colossal establishment, which in 1856 employed 3,000 people, and the buildings of which covered 12 acres of land, there were 20 infusion vessels

* Add 0'9 of mURE.
† Add 1'5 mURE; the albumen added to the sugar.
12 to 14 feet deep, and 7 wide. A cwt. of raw roots cost 7d., and the dried root contained 40 to 47 per cent. of sugar; the capital employed was eighty millions of francs.

Whether the juice is extracted from fresh or dried beets the subsequent processes are the same. The juice, having been extracted either by infusion or by submitting the rasped pulp to hydraulic pressure, is placed in a shallow vessel, and mixed with as much milk of lime as renders it strongly alkaline; it is then boiled, generally by means of a copper coil heated by high-pressure steam. The excess of lime is removed by passing a stream of carbonic acid gas through the liquid. The gas is generally produced by forcing a stream of air through an enclosed coke fire. The liquid is next filtered through cloth concentrated to a specific gravity of 25° B., filtered through animal charcoal, and treated in all respects similarly to ordinary cane sugar in a refinery. Though the vacuum-pan is employed in most beet-root establishments, there are some manufacturers who continue to evaporate in open vessels.

The large amount of water which has to be removed in the concentration of beet-root syrups involves the use of so much fuel that, to economize it, an ingenious apparatus has been constructed by M. Cail, of Paris. The principle adopted is to use the steam generated from the ebullition of liquid in one vessel for boiling another, the steam from which in like manner boils a third.

Maple Sugar.—The manufacture of sugar from the juice of a species of maple-trees, which grow spontaneously in many of the uncultivated parts of North America, appears to have been first attempted about 1752, by some of the farmers of New England, as a branch of rural economy. The total production of maple sugar has been estimated at 45 millions of pounds, or the one hundred and twenty-fifth part of the whole quantity of cane sugar extracted for the use of man. The manufacture of maple sugar diminishes yearly in proportion as the native American forests are cut down. See Sugar, vol. ii.
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Potato Sugar.—The manufacture of sugar from starch derived from potatoes, from woody matter, and from rags, can be effected by treating them with sulphuric acid and heat; but the process, interesting though it is, is rarely if ever adopted at present, as the sugar is inferior in quality to that obtained from the cane, and dearer in price. See Potato Sugar, vol. ii.

Animal charcoal.—One of the most important considerations for a sugar refiner is to furnish himself supply with bone charcoal of the best quality, and to devote unusual attention to the process of revivification. The theory of the action of bone charcoal upon solutions of raw sugar and other colored liquids need not be discussed here. It may, however, be observed, that but little is known upon the subject, and that the behavior of bone charcoal with respect to metallic oxides and various salts is as remarkable as its action upon coloring matter.

After the raw liquor has been passed continuously through a filter of bone charcoal, the decolorizing power of the charcoal becomes impaired, and finally lost. This power may be more or less restored by the following means:—1st. Washing with water. 2d. Fermentation. 3d. Washing with weak hydrochloric acid. 4th. Long exposure to air and moisture. 5th. Heating to redness.

The last plan being the only one which does not materially injure the charcoal, and most completely restores its power, is the course almost invariably adopted; it is however preceded by washing with water.

Various forms of apparatus for reviving charcoal have been proposed and adopted, but the following methods are the chief at present used:—

1st. Burning in iron pipes. A furnace about six feet in length, and eighteen inches wide, is placed between two rectangular chambers with which it communicates; each chamber contains thirty-two east-iron pipes of four inches diameter and nine feet in length, whose extremities pass through the top and bottom of each chamber; to the lower end of each pipe a sheet-iron cooler is suspended. When the charcoal kiln is in use, the pipes filled with charcoal are maintained at a dull red heat, and the charcoal is withdrawn from the coolers in measured quantities at such intervals of time as to allow it to be four hours under the action of the heat.

The advantages of this plan are cheapness of first cost and simplicity; its disadvantages are first, that the charcoal is unequally burnt, the pipes near the furnace being more heated than those further removed from it; second, the kilns require frequent repairs, some of the pipes being destroyed by the fire; third, the amount of fuel required is large; fourth, the pipes are apt to become choked.

2d. Burning in fire-clay chambers. This plan, proposed by Mr. Parker, of London, and improved by Mr. G. F. Chantrell, of Liverpool, is becoming generally adopted. The plan consists in arranging narrow chambers, composed of fire-tiles, and containing charcoal, between small furnaces. Fig. 642 shows a section of Mr. Chantrell's kiln through one of the fire-places; figs. 643 a, 643 b, two front views of the same. c is the fire-door; n the furnace; the products of combustion issue through apertures in the arched roof of the furnace, and are compelled to take a zigzag course to the flue a, by means of horizontal floors of tiles, each floor being open at alternate ends. n, m are apertures for cleaning the flues or inspecting the state of the kiln; l, k, the coolers; m, the
measuring-box or receiver; *r*, a heated floor for drying the charcoal previous to being reburned; *s*, the firing floor. The advantages of this system are, first, the charcoal is very equally burnt; second, the amount of fuel required is small, not reaching ten per cent. of the charcoal reburned; third, non-liability to get out of order; the chief disadvantage is the amount of first cost.

3d. Reburning in rotating cylinders. This plan, like the former, the subject of a patent, is used at the extensive establishment of Mr. G. Torr, London, the regularity and the excellence of the result being considered by him a sufficient composition for the costliness of the process.

4th. Reburning by means of superheated steam. This ingenious method, were it not for the expense of the apparatus, and practical difficulties, would supersede the previous methods. The apparatus is the invention of MM. Laurens & Thomas of Paris. A furnace is constructed, in the flues of which a number of cast-iron tubes, connected together and ranged in order, are placed; the products of combustion, after maintaining the pipes at a high temperature, impart heat likewise to the vase-shaped vessel before entering the chimney. A jet of steam being passed through, the pipes becomes sufficiently superheated to expel the moisture from the charcoal contained in the receiver, and subsequently to raise it to a temperature of 600° F. This is sufficient to effect destructive distillation of the coloring matter absorbed by the charcoal. The process takes about eight hours; the advantages of this method consist in the steam coming in absolute contact with every single grain of charcoal; the distillates are effectually removed, and there is little or no risk of the charcoal being subjected to too high a temperature; but the plan is expensive and inconvenient, and has not been adopted in England.

To reurn charcoal the best methods are those which most rapidly remove the water, raise the temperature of each grain of charcoal to a uniform temperature of 700° Fahr., and which admit of its being readily cooled without contact with the air. The influences of time and temperature, in the reurning process, are very marked; in the best regulated refineries the decoloring power of the charcoal is frequently examined and recorded, and an analysis of the charcoal is made each month.

SULPHURIC ACID, Vitriolic Acid, or Oil of Vitriol. (Acid sulfurique, Fr.; Säure-sulfäure, Germ.) This important substance now forms an extensive article of manufacture. It appears to have been known several centuries back. It is found in large quantities in the mineral kingdom, combined with bases, in some rivers in the free state, and in such quantity as to render the water acid. It was previously prepared by the distillation of sulphate of iron or green vitriol, from which it received its name of oil of vitriol or vitriolic acid. This process is even now carried on in some parts of Germany to a certain extent. It was afterwards found that it might be produced by the combustion of sulphur, and the ultimate further oxidation of the sulphurous acid, thus obtained, by the means of nitric acid; and from time to time improvements have been made in the process, until it is now almost, perhaps entirely, perfect, and is the process most generally adopted. We shall proceed to describe the process more fully, as it is now carried on.

In the first place the sulphur is burnt on suitable hearths, and the sulphurous acid produced is carried by flues, together with some nitrous and nitric acids, generated in the same furnace from a mixture of nitre and sulphuric acid, into the large leaden chambers, into
SULPHURIC ACID.

The apparatus necessary for the manufacture of sulphuric acid is
1. Hearth on which the sulphur is burnt. 2. Iron pot for the nitre. 3. Leaden chambers. 4. Steam boiler. 5. Concentrating pans (leaden). 6. Platinum or glass retorts.

The place where the sulphur is burnt is a kind of furnace, but instead of the grate there is a stone hearth or iron plate, called the sole. The nitre pot or pan is of cast iron. In it the nitre is decomposed by the sulphuric acid, and it is placed in the furnar when required. The leaden chamber has the form of a parallelepiped, the size varying with the amount of work required to be done. To produce 10 tons of oil of vitriol weekly, the chamber should have a capacity of 53,000 cubic feet; or a length of 187 feet, a breadth of 123 feet, and a height of 15 feet. (Pharmaceutical Times, Jan. 2, 1847.) The bottom is covered to the depth of 3 or 4 inches with water acidulated with sulphuric acid. These leaden chambers are sometimes divided into 3 or 4 compartments by leaden curtains placed in them, which cause the more perfect mixture of the gases. Fig. 643 is a drawing of one thus divided, taken from Pereira's Materiä Medica.

Oil of Vitriol Chambers.

a, Steam boiler. b, Section of furnace or burner. d and f, Leaden curtains from the roof of the chamber to within six inches of the floor. e, Leaden curtain rising from the floor to within six inches of the roof. g, Leaden conduit or vent-tube for the discharge of uncondensable gases. It should communicate with a tall chimney to carry off these gases, and to occasion a slight draught through the chamber.

These curtains serve to detain the vapors, and cause them to advance in a gradual manner through the chamber, so that generally the whole of the sulphuric acid is converted into sulphuric acid and deposited in the water at the bottom before it reaches the discharge pipes; but as such is not always the case, there are sometimes smaller chambers, also containing water, appended to the larger, from which they receive the escaping gases before they are allowed to pass out in the air, and thus prevent loss. These smaller chambers are seen in fig. 644 c, d, also taken from Pereira's Materiä Medica.

Oil of Vitriol Manufactory.
a, Sulphur burner or furnace. b, First leaden chamber. c, d, Second and third smaller leaden chambers. e, Steam boiler. f, Flue pipe or chimney of the furnace. g, Steam pipe. h, The flue or pipe conveying the residual gas from the first to the second leaden chamber. i, Pipe conveying the gas, not absorbed in the first and second chamber, into the third. k, Flue or waste pipe. l, Manhole, by which the workmen enter the chamber when the process is not going on. m, Pipe for withdrawing a small portion of sulphuric acid from the chamber, in order to obtain its sp. gr. by the hydrometer.
Another method for preventing this loss has been contrived by M. Gay-Lussac, and made the subject of a patent in this country by his agent, M. Sautter. It consists in causing the waste gas of the vitriol chamber to ascend through the chemical cascade of M. Clement-Desormes, and to encounter there a stream of sulphuric acid of specific gravity 1.750. The nitrous acid gas, which is in a well regulated chamber always slightly redundant, is perfectly absorbed by the said sulphuric acid; which, thus impregnated, is made to trickle down through another cascade, up through which passes a current of sulphurous acid, from the combustion of sulphur, in a little adjoining chamber. The condensed nitrous acid gas is thereby immediately transformed into nitrous gas, (dioxide of azote,) which is transmitted from this second cascade into the large vitriol chamber, and there exercises its well known re-action upon its airiform contents. The economy thus effected in the sulphuric acid manufacture is such that for 100 parts of sulphur 3 of nitrate of soda will suffice, instead of 9 or 10 as usually consumed.

The flue or waste pipe serves to carry off the residual gas, which should contain nothing but the nitrogen of the atmosphere, which has been introduced.

Having now detailed, with sufficient minuteness, the construction of the chamber, we shall next describe the mode of operating with it. There are at least two plans at present in use for burning the sulphur continuously in the oven. In the one, the sulphur is laid on the hearth, (or rather on the flat hearth in the separate oven, above described,) and is kindled by a slight fire placed under it; which fire, however, is allowed to go out after the first day, because the oven becomes by that time sufficiently heated by the sulphur flames to carry on the subsequent combustion. Upon the hearth an iron tripod is set, supporting, a few inches above it, a hemispherical cast-iron bowl (basin) charged with nitre and its decomposing proportion of strong sulphuric acid. In the other plan, 12 parts of bruised sulphur, and 1 of nitre, are mixed in a leaden trough on the floor with 1 of strong sulphuric acid, and the mixture is shovelled through the sliding iron door upon the hot hearth. The successive charges of sulphur are proportioned, of course, to the size of the chamber. Length of the largest, which is 120 feet long, 29 broad, and 16 high, 12 cwt. are burned in the course of 24 hours, divided into 6 charges, every fourth hour, of 2 cwt. each. In chambers of one-sixth greater capacity, containing 1,400 cubic metres, 1 ton of sulphur is burned in 24 hours. This immense production was first introduced at Chauvay and Dieuze, under the management of M. Clement-Desormes. The bottom of the chamber should be covered at first with a thin stratum of sulphuric acid, of sp. gr. 1.07, which decomposes hyponitritic acid into oxygen and binoxide of nitrogen; but not with mere water, which would absorb the hyponitritic acid vapors, and withdraw them from their sphere of action. The crystalline compound, described below, is often formed, and is deposited at low temperatures, in a crust of considerable thickness (from one-half to one inch) on the sides of the chamber, so as to render the process inoperative. A circumstance of this kind occurred, in a very striking manner, during winter, in a manufacture of oil of vitriol in Russia; and it has sometimes occurred, to a moderate extent, in Scotland. It is called, at Marseilles, the maladie des chambres. It may be certainly prevented, by maintaining the interior of the chamber, by a jet of steam, at a temperature of 100° Fahr. When these crystals fall into the diluted acid at the bottom, they are decomposed with a violent effervescence, and a hissing gurgling noise, somewhat like that of a tun of beer in brisk fermentation.

M. Clement-Desormes demonstrated the proposition relative to the influence of temperature by a decisive experiment. He took a glass globe, furnished with three tubulures, and put a bit of ice into it. Through the first opening he then introduced sulphurous acid gas; through the second, oxygen; and through the third binoxide of nitrogen. While the globe was kept cool by being plunged in iceed water, no sulphuric acid was formed, though all the ingredients essential to its production were present. But on exposing the globe to a temperature of 100° Fahr., the four bodies began immediately to react on each other, and oil of vitriol was condensed in visible strica.

The introduction of steam is a modern invention, which has vastly facilitated and increased the production of oil of vitriol. It serves, by powerful agitation, not only to mix the different gaseous molecules intimately together, but to impel them against each other, and thus bring them within the sphere of their mutual chemical attraction. This is its mechanical effect. Its chemical agency is still more important. By supplying moisture at every point of the immense included space, it determines the formation of hydrous sulphuric acid, from the compound of nitric, hypo-nitric, sulphurous, and dry sulphuric acids.

Besides the process here described, which is called the continuuous process, there was another formerly adopted, called the intermitent process. This was also carried on in large leaden chambers; but instead of a continuous stream of air, as passes into the chambers, through the furnace by the continuous process, the chambers were opened now and then to introduce fresh atmospheric air. This process is, however, now generally abandoned, on account of the difficulties and delays attending it, though it afforded large products in skillful hands. The following is just an outline of the process—On the intermittent plan, after the consumption of each charge, and condensation of the product, the chamber was opened.
and freely ventilated, so as to expel the residuary nitrogen, and replenish it with fresh atmospheric air. In this system there were four distinct stages or periods:—1. Combustion for two hours; 2. Admission of steam, and settling for an hour and a half; 3. Conversion for three hours, during which interval the drops of strong acid were heard falling like heavy hailstones on the bottom; 4. Purging of the chamber for three-quarters of an hour.

The complicated changes which take place in the leaden chambers during the conversion of the sulphurous acid into sulphuric acid, were first traced by M. Clement-Desormes. He showed that hypnontic acid and sulphurous acid gases, when mixed, react on each other through the intervention of moisture; that there thence resulted a crystalline combination of sulphuric acid, binoxide of nitrogen, and water; that this crystalline compound was instantly destroyed by more water, with the separation of the sulphuric acid in a liquid state, and the disengagement of binoxide of nitrogen; that this gas re-constituted hypnontic acid at the expense of the atmospheric oxygen of the leaden chamber, and thus brought matters to their primary condition. From this point, starting again, the particles of sulphur in the sulphurous acid, through the agency of water, became fully oxygenated by the hypnontic acid, and fell down in heavy drops of sulphuric acid, while the binoxide of nitrogen derived from the hypnontic acid, had again recourse to the air for its lost dose of oxygen. This beautiful interchange of the oxygogenous principle was found to go on, in their experiments, till either the sulphurous acid or oxygen in the air was exhausted.

By a modification of this last process, the manufacture of sulphuric acid from sulphur and nitre may be elegantly illustrated. Take a glass globe with an orifice at its top large enough to take a lead stopper, through which are fixed five glass tubes; one in connection with a flask generating sulphuric acid from copper turnings and sulphuric acid; the second in connection with a gasometer supplying binoxide of nitrogen; the third in connection with a vessel capable of supplying a tolerable current of steam; the fourth connected to another gasometer supplying atmospheric air; and the fifth, which is left open, does not project far into the globe, and serves to carry off the residual nitrogen. By regulating the influx of the different gases and steam, the solid white crystalline compound may be alternately formed and again decomposed. The bottom of the glass globe is formed like a funnel, and the sulphurous acid, when formed, thus runs down the sides into a bottle placed beneath. Some difference of opinion exists about the composition of the crystalline compound thus formed sometimes in leaden chambers. It is probably a compound of sulphuric acid and binoxide of nitrogen NO\(_2\)+2SO\(_2\), but it is not decided if it contains water or not.

Pelloget (Ann. Chim. et Phys. 3ème sér. xii, 1844) states that the sulphuric acid is oxidized incessantly and exclusively by nitric acid only, and he accounts for it in this way:—The hypnontic acid (NO\(_2\)) by contact with water is converted into nitric acid, and nitrous acid 2NO\(_2\)+HO=HNO\(_3\)+NO, and the nitrous acid (NO\(_2\)) is again decomposed by more water into nitric acid and binoxide of nitrogen 3NO\(_2\)+HO=HNO\(_3\)+2NO\(_2\). The binoxide of nitrogen by contact with atmospheric air is again converted into hypnontic acid (NO\(_2\)+O\(_2\)+NO), which goes through the same changes as before.

There are some points in the manufacture of sulphuric acid which require attention.

1st. If the heat in the sulphur furnace is too high, or when there is not a sufficient supply of air, some sulphur sublimes, and is condensed in the chamber, and at last falls into the sulphuric acid at the bottom of the chamber. By this means, not only is less sulphuric acid produced, but the sulphuric acid, when drawn from the chamber, contains some sulphur in suspension: in this case it must be allowed to stand until as much of the sulphur, which may be collected, washed, dried, and again used. If the sulphur were not removed before concentrating, it would, at the temperature requisite for evaporation, decompose the sulphuric acid, with the escape of sulphurous acid gas, and hence much sulphuric acid would be lost. The reaction that would take place is represented by the following equation:—

\[
2\text{H}_2\text{SO}_4 + 8\text{H} = 3\text{SO}_3 + 2\text{H}_2\text{O}
\]

2d. If there is not a sufficient quantity of steam admitted into the chamber, the solid compound of sulphuric acid and binoxide of nitrogen, above mentioned, would be formed.
on the sides of the chamber, and thus remove the oxidizing agent from action, and hence a large quantity of sulphurous acid would escape by the waste-pipe unchanged.

3d. A deficiency of nitric acid in the chamber also causes great loss; the sulphurous acid as in the former case, escaping unoxidized.

The first of these three subjects was counteracted by M. Grovelle, who, taking advantage of an idea put forth by M. Clement Desormes, constructed a furnace for burning the sulphur, so as to have a double current of air. He substituted for the sole of the furnace some parallel bars of iron, on which were placed cast-iron pans or boxes, bound together, but leaving intervals for the entrance of air between each: these were filled with sulphur, which was then ignited, and thus a plentiful supply of air was constantly kept up.

Fuming, or Nordhausen sulphuric acid. At Nordhausen and other parts of Saxony, sulphuric acid continues to be made upon the old plan. This consists in first subjecting sulphate of iron or green vitriol to a gentle heat, by which it is deprived of its water of crystallization; it is then distilled in earthenware, tubular, or pear-shaped retorts, of which a large number are placed in a gallery furnace. Fig. 643, the fire-place; a b b, chamber on each side of the fire-place, for depriving the green vitriol (c e) of its water.

To these retorts are adapted earthenware receivers, into which some ordinary sulphuric acid is previously placed, to condense all the anhydrous sulphuric acid which comes over. The heat is raised gradually, and at last the retorts are subjected to an intense heat, which is kept up for several hours.

Some sulphurous acid gas escapes, arising from the decomposition of some of the sulphuric acid of the sulphate by the oxide of iron, and nothing remains in the retorts but sesquioxide of iron.

\[ 3\text{FeSO}_4 = \text{Fe}_2\text{O}_3 + 2\text{SO}_2 + \text{SO}_3 \]


Anhydrous sulphuric acid. This is most easily obtained by subjecting the Nordhausen sulphuric acid to a gentle heat in a glass retort, to which is adapted a dry receiver placed in ice. White fumes of anhydrous sulphuric acid come over and are condensed in the receiver. Care must be taken to avoid water coming into contact with it, as it unites with it with some violence.

\[ \text{HSO}_3\text{O}_3 = \text{HSO}_4 + \text{SO}_3 \]


It is best to have a receiver, which can be hermetically sealed as soon as the operation is completed.

Properties of the different Sulphuric Acids.

Anhydrous sulphuric acid. \(\text{SO}_3\). This is a white crystalline body, very much resembling asbestos in appearance. Exposed to the air, some of it absorbs moisture, and the rest flies off in white fumes. Dropped into water it produces a hissing noise, just like red-hot iron, and in large quantities causes explosion. It melts at 66° Fahr., and boils at about 120° Fahr. The sp. gr. of the liquid, at 78° Fahr., is 1.97, (Porvira,) and that of its vapor 3.0, (Mitscherlich.) It does not present acid properties unless moisture be present.

Nordhausen sulphuric acid. \(\text{HSO}_4\), \(\text{SO}_3\). This is an oily liquid, generally of a brown color, (from some organic matter,) which gives off white fumes of anhydrous sulphuric acid when exposed to the air. Its sp. gr. is about 1.9. It is imported in stoneware bottles, having a stoneware screw for a stopper. It is probably only a solution of anhydrous sulphuric acid in ordinary oil of vitriol, as, after being subjected to a gentle heat, nothing remains but the latter. It often contains several impurities. It is principally used for dissolving indigo, which it does completely without destroying the color.

Ordinary sulphuric acid or oil of vitriol. \(\text{HSO}_4\). Sp. gr. 1.845. This, when pure, a colorless, transparent, highly acid, and most powerful corrosive liquid. It is a very strong mineral acid, one drop being sufficient to communicate the power of reddening litmus paper to a gallon of water, and produces an ulcer if placed upon the skin. It chars most organic substances. This depends upon its attraction for water, which is so great that, when exposed in an open vessel, it imbibes one-third of its weight from the atmosphere in twenty-four hours, and fully six times its weight in a few months. Hence it should be kept excluded from the air. If four parts, by weight, of the strongest acid be suddenly mixed with one part of water, then at 50° Fahr., the temperature will rise to 390° Fahr.; while, on the other hand, if four parts of ice be mixed with one of sulphuric acid, they immediately liquefy and sink the thermometer to 4° below zero. In this last case the heat, that would otherwise

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have been given off, has been employed in liquefying the ice. Upon mixing the acid and water they both suffer condensation, the dilute acid, thus formed, occupying less space than the two separately, and hence the evolution of heat. This affinity for water, which sulphuric acid possesses, is often made use of for evaporating liquids at a low temperature. The liquid is placed in a dish over another dish containing sulphuric acid, and both are placed under the receiver of an air pump. Such is the rapidity with which the evaporation is carried on, that if a small vessel of water be so placed it will speedily be frozen. Sulphuric acid is decomposed by several substances when boiled with them; such are most organic substances, sulphur, phosphorus, and several of the metals, as mercury, copper, tin, &c.

Sulphuric acid of sp. gr. 1.845, boils at about 620° Fahr., and may be distilled unchanged. This is the best way to obtain it pure. It is a most powerful poison. If swallowed in its concentrated state, even a small quantity, it acts so powerfully on the throat and stomach as to cause intolerable agony and speedy death. Watery diluents mixed with chalk or magnesia are the readiest antidotes.

Ordinary oil of vitriol generally contains some sulphate of lead, which will be precipitated, as a white powder by dilution with water; since so much of it is made from iron pyrites at the present day, it contains arsenic in variable quantities. The best test for sulphuric acid, either free or combined; as soluble salts, is a salt of barium. An extremely small quantity of sulphuric acid, or a soluble salt of it, is thus easily detected by the grayish-white cloud of sulphates of baryta which it occasions in the solution. 100 parts of the concentrated acid are neutralized by 143 parts of dry pure carbonate of potash, and by 110 of dry pure carbonate of soda.

The presence of saline impurities in sulphuric acid may be determined by evaporating a certain quantity to dryness in a platinum capsule. If more than 2 grains of residue remain out of 500 of acid, it may be considered impure. Of all the acids, the sulphuric is most extensively used in the arts, and is, in fact, the primary agent for obtaining almost all the others, by disengaging them from their saline combinations. In this way nitric, hydrochloric, tartaric, acetic, and many other acids, are procured. It is employed in the direct formation of alum, of the sulphates of copper, zinc, potassa, soda; in that of sulphuric ether, of sugar by the saccharification of starch, and in the preparation of phosphorus, &c. It serves also for opening the pores of skins in tanning, for clearing the surface of metals, for determining the nature of several salts by the acid characters that are disengaged, &c.

According to Graham there are three hydrates of sulphuric acid besides the Nordhausen acids, viz.:

- Monohydrate of sulphuric acid, oil of vitriol, of sp. gr. 1.845. HSO\(_4\). This acid is a dense oily, colorless liquid. Boils at 620° Fahr., and freezing at—29° Fahr., yielding sometimes regular six-sided prisms of a tabular form.
- Biskihydrate of sulphuric acid, sometimes called Eisöl, (ice oil), sp. gr. 1.78. HSO\(_4\)+H\(_2\)O.
- In cold weather of this density readily freezes, and produces large, hard crystals, somewhat resembling crystals of carbonate of soda. The melting point of these crystals is 42° Fahr. If the density be either augmented or lessened the freezing point is lowered. The crystals have a sp. gr. 1.924.
- Trihydrate of sulphuric acid. Acid of sp. gr. 1.632. HSO\(_4\)+2H\(_2\)O. This acid is obtained by evaporating a dilute acid in vacuo at 212° Fahr. It is in the proportions contained in this hydrate that sulphuric acid and water undergo the greatest condensation when mixed.

TANGLE. Laminaria digitata of Lamouroux. See ALC.E.

TANNIN, or TANNIC ACID. (Tannin, Fr.; Gertstoff, Germ.) Under the name tannin were formerly understood all those astringent principles which were capable of combining with the skins of animals to form leather, of precipitating gelatine, of forming blackish brown precipitates with the persists of iron, and of yielding nearly insoluble compounds with some c. the organic alkalies. But it has of late years been proved that there are several different kinds of tannin acid, most of which possess an acid reaction.

These principles are widely diffused in the vegetable kingdom; most of our forest trees, as the oak, elm, pines, fir, &c.; pear and plum trees contain it in variable quantities.

It is also found in some fruits. Many shrubs, as the sumach and whortleberry, also contain it in large quantities, and on that account are largely used in dyeing and tanning. The roots of the tormentillas and bistort are also powerfully astringent from containing it. Coffee and tea also contain a modification of this principle. The astringent principle in all the above mentioned (except coffee) precipitates the persists of iron bluish black, or if a free acid be present the solution becomes dark green. The astringent principle of many vegetables precipitates the persists of iron of a dark green,—such as catechin, kino, &c. Some few plants contain another modification of this astringent principle, which precipitates the persists of iron of a gray color,—such are rhatany, the common nettle, &c.
Many of these tannic acids have received names which refer to the plants from which they are obtained. The most important and best known of all these is the **gallo-tannic acid**, or that which is extracted from gall-nuts. There are also **querce-tannic acid**, from the oak; **morit-tannic acid**, or that from the fustic, (morus tinctoria,) &c.

The only one which need be described here is the **gallo-tannic acid**; it is, in fact, the only one which is perfectly known. It is usually obtained from the gall-nuts, which are excised or removed from the leaves of a species of oak (quercus infectoria) by the puncture of a small insect, by the process first proposed by M. Pelouze, which consists in exhausting the powdered gall-nuts by allowing ordinary ether to percolate through them in a proper apparatus. The ether, which always contains some water, separates at the bottom of the apparatus into two distinct layers; the under layer, being the water, containing all the tannic acid, and the upper one, the ether, containing the gallic acid and coloring matter. The solution of tannic acid is washed with ether and evaporated gently to dryness, when the gallo-tannic acid is left as a pale buff-colored amorphous residuum.

Some gall-nuts contain as much as 67 per cent. of gallo-tannic acid, and about 2 per cent. of gallic acid, (Guibourt.) Gallo-tannic acid is freely soluble in water, soluble in diluted alcohol, slightly in ether. The tannic acids are all remarkable for the avidity with which they absorb oxygen; the gallo-tannic acid becoming gallic acid.

A saturated aqueous solution of gallo-tannic acid is precipitated by sulphuric, hydrochloric, phosphoric, and some other acids. When boiled for some time with diluted sulphuric or hydrochloric acid it is converted into sugar and gallic acid, (Strecker;) the latter crystallizes on cooling, whilst the glucose remains in solution.

\[
\text{Gallo-tannic acid.}\]

\[
C_8H_8O_14 + 10\text{HO} = 3(3\text{HO} C_6H_4\text{O}) + C_8H_8\text{O}_{12}\text{H}_2\text{O},
\]

Gallo-tannic acid.

Gallic acid.

Gluose.

The composition of the gallo-tannates is but imperfectly known, and it is not decided if the acid be dibasic or tribasic. A solution of gallo-tannic acid gives, with persulphate of iron, a bluish black precipitate, which is the basis of ordinary black writing ink. The most remarkable compound of gallo-tannic acid is that which it forms with gelatine, which is the basis of leather. See Tanning.

By the reaction of heat gallo-tannic acid is converted into pyrogallic acid, and this distinguishes it from the other species of tannic acid, as they do not yield pyrogallic acid when subjected to the same treatment.

The following formula will show the relation existing between gallo-tannic acid, gallic acid, and pyrogallic acid.

\[
\text{Gallo-tannic acid.}\]

\[
C_8H_8O_14 + 10\text{HO} = 3(3\text{HO} C_6H_4\text{O}) + C_8H_8\text{O}_{12}\text{H}_2\text{O}, 2\text{eq.}
\]

gallic acid.

pyrogallic acid.

When powdered nut-galls are made into a paste, with water, and allowed to ferment for some considerable time, with occasional stirring to facilitate the absorption of oxygen, the gallo-tannic acid is almost entirely converted into gallic acid.

\[
\begin{align*}
\text{1 eq. tannic acid} & = 3 \text{eq. gallic acid} = C_8H_8O_{18} \\
\text{24 eq. oxygen} & = \frac{4 \text{eq. water}}{12 \text{eq. carbonic acid} = C_8H_8O_{18}}
\end{align*}
\]

TANNING. There have been several patents for quickening the tanning process, but we shall mention only one or two here.

The following is taken from the Bavarian Journal of Arts and Trades, and is known as Knoderer's tanning process.

It is well known that the absence of atmospheric air greatly facilitates the process of tanning, and in order to effect this the process must be carried on in vacuo.

The vessel, in which the tanning substance is kept, has to be made air-tight, and at the same time no metal can be used for the expensive one, copper. Iron, as well as zinc, is affected by the tanning substance, and wood can only be used when its pores have been stopped by some varnish which effectually prevents the passage of air into the vessel.

The process is carried on as follows:—When the hides are taken from the wash, all the water contained in them is expelled by a powerful press. They are then placed in a barrel, having a rotatory motion, together with the necessary amount of tanning material, and enough water added to keep the contents of the barrel moist.

The man-hole is now closed, and the air pumped out as completely as possible; this being done, the stop-cock is closed, and a piece of lead pipe is added to the conducting tube; this lead pipe communicates with a tank which contains tanning fluid of proper strength.
TANNING.

If the stop-cock is now opened, the tanning fluid rushes rapidly into the barrel, and when a sufficient quantity has been admitted, the stop-cock is closed, and the barrel is now rotated for an hour, or half an hour, according to the quantity of hides contained in it. After two or three hours’ rest, the rotation is again continued to the end of the operation.

The advantages of this process are: First, by the air being rarefied the pores of the skins are opened, and thus more rapidly absorb the tanning principle; and the tannic acid is not so rapidly converted into gallic acid, which is of no use in tanning.

Secondly, the rotatory motion facilitates the extraction of the tannic acid from the bark, &c. Thus the hides are completely tanned in a much less time than without rotatory motion, as will be seen by the following table, based on actual experiments.

<table>
<thead>
<tr>
<th>Hides</th>
<th>Time required for tanning in</th>
<th>Time required when mover is in motion.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calf skins</td>
<td>from 6 to 11 days.</td>
<td>-</td>
</tr>
<tr>
<td>Horse hides</td>
<td>35 40</td>
<td>4 to 7 days.</td>
</tr>
<tr>
<td>Light cow hides</td>
<td>30 35</td>
<td>14 18</td>
</tr>
<tr>
<td>Cow hides (minkling)</td>
<td>40 45</td>
<td>12 16</td>
</tr>
<tr>
<td>Heavy cow hides</td>
<td>50 60</td>
<td>18 20</td>
</tr>
<tr>
<td>Ox hides (light)</td>
<td>50 60</td>
<td>22 50</td>
</tr>
<tr>
<td>Ox hides (first quality)</td>
<td>70 90</td>
<td>20 50</td>
</tr>
</tbody>
</table>

At the same time a large percentage of bark is saved.

A patent was taken out by E. Welsford, of Bona, Algeria, in 1859. Instead of employing oak bark or the ordinary tanning substances, he uses the leaves of the different trees and shrubs of the family Ternstachaeae, as the Pistacea terebinthus, Pistacea Atlantica, Pistacea lentiscus, &c., abounding on the coast of the Mediterranean and elsewhere. He forms an infusion or decoction of the leaves for tanning.

A machine has been invented by Mr. S. F. Cox, of Bristol, for effecting the various processes of depilating, scudding, striking, smoothing, sticking, and stretching, which are now usually effected by hand. The hide or skin is carried by a cylinder or roller, or by a moving bed or platform, which presents it gradually to a revolving spiral bar or knife or rubber. The spiral consists of a right and left handed screw, so arranged as to rub or scrape the hide, &c., from the centre toward the sides, or it may consist of a single thread of a screw, or several.

The roller or bed which carries the hide or skin is pressed toward the revolving spiral instruments by springs or otherwise, and is gradually advanced by a ratchet, so that the whole of the hide is uniformly and successively exposed to the action of the revolving spiral instruments. A treadle is employed for withdrawing the roller or bed from the revolving spiral to facilitate the adjustment of the hide.

Vegetable Substances used in Tanning.

No two substances will produce the same quality leather, either in texture or color. Doubtless this is owing to a different variety of tannic acid contained in the material, though unfortunately very little is understood about it, the subject not having been much studied. Some things contain a large proportion of tannin but do not fill up the pores of the hide; gambir, for instance, tans quickly, but does not make a heavy leather.

Oak bark. (Quercus pedunculata.)—This bark is preferred to all other materials for tannage, since it produces the best leather for most purposes. The oak bark of this country is considered superior to that of any other part of Europe. The bark season in England is usually from the middle of April to the end of May. It is essential that the sap should run well before the bark is stripped, as it contains most tannin when the sap begins to run.

English coppice oak bark.—This bark is very similar to timber oak bark, but is lighter and thinner, and contains more tannin, as there is not so much epidermis, (which contains none.) It is preferred for tanning light goods. Coppice bark is stripped at the same time of year as the heavier sorts.

Belgian oak bark.—This bark is similar to the English, and is imported, chopped into small pieces, chiefly from Antwerp; it does not sell for so high a price as the English, for it is said not to contain so much tannin.

Chopped bark is simply bark with the rough epidermis scraped off and then chopped into pieces.

Cork-tree bark. (Quercus suber.)—This is the inner bark of the cork tree, the cork growing on the exterior contains no tannin. It is imported from the Island of Sardinia, Tuscany, and the coast of Africa; the Sardinian is the best, and may easily be distinguished by its color and weight, being of a pinkish hue throughout, and is stouter and heavier than the Tuscan or African. Cork-tree bark contains a great deal of tannin, but deposits little "bloom" on the leather.

There are four species of oak chiefly used for tanning in America. Spanish oak bark is thick, black, and deeply furrowed, and is preferred for coarse leather. In the Southern States the Spanish oak grows to the height of 80 feet with a diameter of 4 or 5 feet at the trunk, while in the North it does not exceed the height of 30 feet.
TEA.

The common red oak, abundant in Canada and in the Northern States, is very generally employed, though inferior in several respects to the other kinds.

The rock chestnut oak abounds in elevated districts. On some of the Alleghany mountains it constitutes nine-tenths of the forest growth; its bark is thick, hard, and deeply furrowed, but only the bark of the small branches and young trees is used in tanning.

Quercus bark, (Quercus tiliocarpus,) or black oak, grows through the States; its bark is not very thick, but deeply furrowed, and of a deep brown color; the leather tanned from it is apt to tinge the stockings yellow. This tree often attains a height of 90 feet, and a diameter of 4 or 5 feet.

There are other varieties used, but it is needless to mention them here.

Valonia, (Quercus egilops,)—Valonia is the acorn cup of the Quercus egilops. See LEATHER.

Sawdust of commerce is the crushed or ground leaves of Rhus coriaria, and is imported from Sicily. In making the usual ground sawdust the larger branches or sticks are cut out by hand; the smaller ones do not pulverize, and are taken out by sifting, the stems of the leaves are put under the mill a second time. In grinding, the calculation is that 335 lbs. of leaves turn out 250 lbs. of fine ground sawdust.

There is naturally, or at least unavoidably, from 3 to 4 per cent. of sand or dirt in the leaves as sent to the mill; this can only be taken out before grinding, but if thoroughly done would cost 1d. &d per cwt, additional, which the trade will not pay.

Minosa bark is the bark of a tree belonging to the order Foliaceae, subdivision Minosace. It is imported from Australia and Tasmania, but is also abundant in the East Indies. Minosa bark is difficult to grind, it is also difficult to extract the tanning; it deposits no bloom, and is, therefore, not much esteemed by English tanners, but is used in the East Indies to a large extent.

Gambir, or terra japonica.—This astringent substance, sometimes called catechu, is produced by boiling and evaporating the brown hard wood of the acacia catechu in water, until the inspissated juice has acquired a proper consistency; the liquor is then strained, and soon coagulates into a mass.

It is frequently mixed with sand and other impurities, has little smell, but a sweet astringent taste in the mouth, and is gritty if it is perfectly pure; it will totally dissolve in water, and the impurities will fall to the bottom. It is chiefly used in England as in the East Indies (whence it is imported) for tanning kips. It is mixed with valonia and sawdust.

Larch bark is used for tanning bassets (sheepskins) for bookbinding, &c., principally in Scotland, where the bark is more abundant, though it is also used in England and Ireland.

Birch bark is used for tanning Russia leather; it is also used by the Laplanders.

Hemlock bark (Abies Canadensis) is one of the principal barks used in America for tanning; it makes a reddish colored leather, and not nearly so good as oak bark leather.

There is a large collection of tanning materials in the Museum at the Royal Gardens at Kew, collected by Mr. W. G. Fry of Bristol, to whom we are indebted for the practical part of this paper.—H. K. B.

TARE, or VETCH, a plant—Vicia sativa—which has been cultivated in this country from the earliest times.

TARTRATES are dibasic salts composed of tartaric acid and oxidized bases, in equivalent proportions. Some of the tartrates are employed in the arts, bitartrate of potash being used as a mordant in dyeing woolen fabrics. Tartrate of chromium is sometimes used in calico printing, and the tartrate of potash and tin in wool dyeing.

The Stockholm tar is regarded as the best; we have a description of the mode in which it is prepared, by Dr. Clarke, in his Travels in Scandinavia.

"The situation most favorable to the process is in a forest near to a marsh or bog, because the roots of the fir, from which tar is principally extracted, are always most productive in such places. A conical cavity is then made in the ground, (generally on the side of a bank or sloping hill,) and the roots of the fir, together with logs and billets of the same, being nearly trucked in a stack of the same conical shape, are let into the cavity. The whole is then covered with turf to prevent the volatile parts from being dissipated, which, by means of a heavy wooden mallet and wooden stumper, worked separately by two men, is beaten down and rendered as firm as possible about the wood. The stack of billets is then kindled, and a slow combustion of the fir takes place as in working charcoal. During this combustion the tar exudes, and a cast-iron pan being at the bottom of the funnel, with a spout which projects through the side of the bank, barrels are placed beneath this spout to collect the fluid as it comes away. As fast as the barrels are filled they are bunged and ready for immediate exportation.

Wood tar is obtained as a secondary product in the manufacture of acetic acid, in the dry distillation of wood.

TEA. The observations of Liebig afford a satisfactory explanation of the cause of the great partiality of the poor, not only for tea, but for tea of an expensive and superior kind. He says: "We shall never certainly be able to discover how men were first led to the use
of the hot infusion of the leaves of a certain shrub, (tea,) or of a decoction of certain roasted seeds, (coffee.) Some cause there must be which will explain how the practice has become a necessary of life to all nations. But it is still more remarkable, that the beneficial effects of both plants on the health must be ascribed to one and the same substance, (theine or caffeine,) the presence of which in two vegetables, belonging to natural families, the products of different quarters of the globe, could hardly have presented itself to the boldest imagination. Yet recent researches have shown, in such a manner as to exclude all doubt, that theine and caffeine are in all respects identical." And he adds, "That we may consider these vegetable compounds, so remarkable for their action on the brain, and the substance of the organs of motion, as elements of food for organs as yet unknown, which are destined to convert the blood into nervous substance, and thus recruit the energy of the moving and thinking faculties." Such a discovery gives great importance to tea and coffee, in a physiological and medical point of view.

At a meeting of the Academy of Sciences, in Paris, lately held, M. Peligot read a paper on the Chemical Combinations of Tea. He stated, that tea contained essential principles of nutrition, far exceeding in importance its stimulating properties; and showed that tea is, in every respect, one of the most desirable articles of general use. One of his experiments on the nutritious qualities of tea, as compared with those of soup, was decidedly in favor of the former.

TENT. We have no space to enter into the history of tents, or describe the varieties which have been used from time to time. A few words on modern tents must suffice:

The hospital marquee is 29 feet long, and 14½ feet wide and 15 feet high. This is supposed to accommodate not less than eighteen nor more than twenty-four men. The height of each tent-pole is 15 feet 8 inches; the length of the ridge-pole, 13 feet 10 inches; the height of the tent walls from the ground, 5 feet 4 inches. The weight of all the material of such a tent is stated by Major Rhodes to be 62 lbs.

Of the circular single-poled tents we have two kinds, the new cotton circular tent, and the new pattern linen circular tent; each tent is provided with a vertical circular wall; that of the cotton tent is 2 feet 6 inches in height, and that of the linen tent is 1 foot. The diameter of each tent is 12 feet 6 inches; the length of the pole about 10 feet. Such a tent accommodates sixteen men.

Major Godfrey Rhodes has introduced a new and improved tent, which has no centre-pole. The frame of the tent is formed of stout ribs of ash, bamboo, or other flexible material. The ends of the ribs are inserted into a wooden head, fitted with iron sockets, and the butts are thrust into the ground, passing through a double twisted rope, having fixed loops at equal distances. The canvas is thrown over this frame-work, and secured within the tent by leather straps to the ground, or circular rope. The present hospital tent, when pitched, covers about 349 square yards. Major Rhodes' hospital tent covers only 62 square yards, and weighs 89½ lbs., while it accommodates an equal number of men. The field tent is made up in one package, 5 feet 6 inches long, weighing 100 lbs.; the guard tent into one package, 7 feet 6 inches long, weighing 52 lbs. The accompanying cuts, figs. 646 and 647,
show Major Rhodes' field tent and the frame thereof. The difference, as it regards weight and convenience, in those tents introduced by Major Rhodes, is very great. We regret our space will not admit of more detail; this, however, is somewhat compensated by the ample detail to be found in a book, *Tents and Tent Life*, published by the patentee.

The ventilation of tents has been admirably effected by Mr. Doyle, to whom we are indebted for the information contained in the following notes on the subject:

The old method of ventilating military tents was very defective. Ventilating openings were made at the top of the tent, but no means were provided for the admission of fresh air. The result was most unsatisfactory, as may be gathered from the following evidence given before the Sebastopol committee:

"The tents were very close indeed at night. When the tent was closed in wet weather, it was often past bearing. The men became faint from heat and closeness." *

* Evidence of Sergeant Dawson, Grenadier Guards.
The problem then was to let in fresh air, and produce a draft without inconveniencing the soldiers as they slept.

The question attracted Mr. Doyle's notice during the period of the camp at Chobham, and it appearing to him to be one of very great importance, he undertook, with the sanction of Lord Raglan, then Master-General of the Ordnance, to try the following experiment:

He caused two openings to be made in the wall of a tent, about 4 feet from the ground, and introduced the air between the wall and a piece of lining somewhat resembling a carriage pocket, fig. 648: a a is the wall of the tent; b, the opening to admit air; c, the lining. It will be seen that air so introduced would naturally take an upward direction, and that this communicating with the openings at the top of the tent, would probably produce the desired effect.

The following extract from the report on this experiment will show the actual result:

"The ventilators (Mr. Doyle's) were found of great use in clearing the tent of the fetid atmosphere consequent upon a number of men sleeping in so confined a space. The men state that the heavy smell experienced before the tent was altered is almost banished."

In subsequent experiments the number of the new openings was increased from two to three, and a greater amount of ventilation thus obtained. The result, according to an official letter of thanks received on the subject, was "quite successful." The improvement has been since adopted into the service, and by these very simple means one of the most fruitful causes of sickness among our soldiers in camp finally removed.

TERRA-COTTA. When moulding is performed for terra-cotta works, sheets of clay are beaten on a bench to the consistency of glazier's putty, and pressed by the hand into the mould; according to the magnitude of the work and the weight it may have to sustain, the thickness of the clay is determined and arranged, and here consists a part of the art it would be impossible to describe, and which requires years of experience in such works to produce great works and fire them with certainty of success. At the Crystal Palace, Sydenham, are several large works manufactured by Mr. J. M. Blashfield, who has extensive terra-cotta works at Stamford. The figure of austria, modelled by John Bele, nine feet in height, and burnt in one piece; the colossal Tritons modelled by the same artist, and other works, are examples. After the moulded article has become sufficiently dry, it is converted to a kiln. A slow fire is first made, and quickened until the heat is sufficient to blend and partially vitrify the material of which the mass is composed; when sufficiently baked, the kiln is allowed to cool, and the terra-cotta is withdrawn.

TEssER.E. The Roman tesserae, of which many very fine examples have been discovered in this country, were, often, natural stones, (sometimes colored artificially,) but generally of baked clay. The beauty of many of these has led to the production of modern imitations, which have been gradually improved, until, in the final result, they far exceed any work of the Romans.

About half a century since Mr. C. Wyatt obtained a patent for a mode of imitating tessellated pavements, by inlaying stone with colored cements. Terra-cotta, imitated with colored cements, has also been employed, but with no very marked success.

Mr. Blashfield produced imitations of these pavements, by coloring cements with the metallic oxides: these stood exceedingly well when under cover, but they did not endure the winter frosts, &c. Bitumen, colored with metallic oxides, was also employed by Mr. Blashfield. In 1839 Mr. Singer, of Vauxhall, introduced a mode of forming tesserae from thin layers of clay. These were cut into the required forms, dried and baked. In 1840 Mr. Proser, of Birmingham, discovered that if the material of porcelain (china clay) be reduced to a dry powder, and in that state be compressed between steel dies, the powder is condensed into about a fourth of its bulk, and is converted into a compact solid substance of extraordinary hardness and density.

This process was first applied to the manufacture of buttons, but was eventually taken up by Mr. Minton and, in conjunction with Mr. Blashfield, Messrs. Wyatt, Parker & Co., was carried to a high degree of perfection for making tesserae.

The process, invented by Mr. Proser, avoided the difficulty altogether of using wet clay.

This change in the order of the potter's operations, although very simple in idea, (and a sufficiently obvious result of reflection on the difficulties attending the usual course of procedure,) has nevertheless required a long series of careful experiments to find out the means of rendering it available in practice.

The power which the hand of the potter has exercised over his clay has been proverbial from time immemorial, but it is limited to clay in its moist or plastic state; and clay in its powdered state is an untreatable material, requiring very exact and powerful machinery to be substituted for the hand of the potter; in order, by great pressure, to obtain the requisite cohesion of the particles of clay.
In the new process, the clay, or earthy material, after being prepared in the usual manner, and brought to the plastic state, as above described, (except that no kneading or tempering is requisite,) is formed into lumps, which are dried until the water is evaporated from the clay.

The lumps of dried clay are then broken into pieces, small enough to be ground by a suitable mill into a state of powder, which is afterward sifted, in order to separate all coarse grains and obtain a fine powder, which it is desirable should consist of particles of uniform size as nearly as can be obtained. The powder, so prepared, is the state in which the clay is ready for being moulded into the form of the intended article by the new process.

The machine and mould used for moulding articles of a small size, in powdered clay, are represented in the annexed drawing, wherein fig. 649 is a lateral elevation of the whole machine.

A a is the wooden bench or table wherein the whole is fixed, that bench being sustained on legs standing on the floor. B D E is the frame, formed in one piece of cast iron; the base b standing on the bench, and being fixed thereto by screw bolts; the upright standard d rising from the base, and sustaining at its upper end the boss e, wherein the nut or box a is fixed for the reception of the vertical screw f. The screw f works through the

box a, and has a handle, c, g, h, applied on the upper end of the screw; the handle is bent downward at g, to bring the actual handle h to a suitable height for the person who works the machine to grasp the handle h in his right hand, and, by pulling the handle h
toward him, the screw \( r \) is turned round in its box, \( a \), and descends. The lower end of the screw \( r \) is connected with a square vertical slider, \( u \), which is fitted into a socket, \( t \), fixed to the upright part \( n \) of the frame, and the slider \( u \) is thereby confined to move up or down, with an exactly vertical motion, when it is actuated by the screw, without deviation from the vertical.

Thus far the machine is an ordinary screw press, such as is commonly used for cutting and compressing metals for various purposes. The tools with which the press is furnished for the purpose of this new process consist of a hollow mould, \( e \), formed of steel, the exterior cavity of the mould being the exact size of the article which is to be moulded. The mould \( e \) is firmly fixed on the base \( b \) of the frame, so as to be exactly beneath the lower end of the piston, \( o \), or plug, \( f \), which is fastened to the lower end of the square slider \( u \), and the plug \( f \) is adapted to descend into the hollow of the mould \( e \) when the slider \( u \) is forced downward by action of the screw \( r \), the plug \( f \) being very exactly fitted to the interior of the mould \( e \).

The bottom of the mould \( e \) is a movable piece, \( n \), which is exactly fitted into the interior of the mould, but which lies at rest in the bottom of the mould \( e \), during the operation of moulding the article therein; but afterward the movable bottom \( n \) can be raised up by pressing one foot upon one end, \( n \), of a pedlar lever, \( n \), the fulcrum of which is a centre pin, \( r \), supported in a standard resting upon the floor, and the end of the lever operates on an upright rod, \( m \), which is attached at its upper end to the movable bottom \( n \) of the mould \( e \).

A small horizontal table, \( \tau \), is fixed round the mould \( e \), and on that table a quantity of powdered clay is laid in a lump in readiness for filling the mould.

The two detached figures, marked figs. 650 and 651, are sections of the mould \( e \), and the plug \( f \), on a larger scale than fig. 649, in order to exhibit their action more completely.

The operation is extremely simple; the operator, holding the handle \( h \) with his right hand, puts it back from him, so as to turn back the screw \( r \), and raise the slider \( u \), and the plug \( f \), quite out of the mould \( e \), and clear above the orifice of the mould, as shown in fig. 649.

Then with a spatula of bone, held in the left hand, a small quantity of the powder is moved laterally from the heap, along the surface of the table \( \tau \), toward the mould \( e \), and gathered into the hollow of the mould with a quiet motion, so as to fill that hollow very completely, and by scraping the spatula evenly across over the top of the mould \( e \), the superfusional powder will be removed, leaving the hollow cavity of the mould exactly filled with the powder in a loose state, and neither more nor less than filled.

Then the handle \( h \), being drawn forward with a gentle movement of the right hand, it turns the screw \( r \), so as to bring the slider \( u \), and the plug \( f \), which thereby descends into the mould \( e \), upon the loose powder wherewith the mould has been filled, and begins to press down that powder, which must be done with a gentle motion without any jerk, in order to allow the air that is contained in the loose powder to make its escape; but the pressure, after having been commenced gradually, is continued and augmented to a great force, by pulling the handle strongly at the last, so as to compress the earthy material down upon the bottom \( n \) of the mould, into about one third the space it had occupied when it was in the state of loose powder. The section, fig. 650, shows this state of the mould \( e \), and the plug \( f \), and the compressed material.

Then the handle \( h \) is put backward again, so as to turn back the screw \( r \), and raise up the slider \( u \), and the plug \( f \), until the latter is drawn up out of the mould \( e \), and clear above the orifice of the mould, as in fig. 649, and immediately afterward by pressure of one foot on the pedal \( n \) of the pedlar lever \( n \), the movable bottom \( n \) of the mould is raised upward in the mould \( e \), so as to elevate the compressed material which is resting upon the bottom \( n \), and carry the same upward, quite out of the mould \( e \), and above the orifice of the mould, as is shown in fig. 651, and then the compressed material can be removed by the finger and thumb.

The compressed material which is so withdrawn is a solid body, retaining the exact shape and size of the interior cavity of the mould, and possessing sufficient coherence to enable it to endure as much handling as is requisite for putting a number of them into an earthenware case or pan, called a sagger, in which they are to be enclosed, according to the usual practice of potters, in preparation for putting them into the potter's kiln for firing; the sagger protects the articles from discoloration by smoke, and from partial action of the flame, which, if a number of small articles were exposed thereto, without being so enclosed, might operate more strongly upon some than upon others of those articles; but by means of the saggers the heat is caused to operate with clearness, uniformity, and certainly upon a number of small articles at once.

After the firing is over, the articles, being removed from the saggers, are in the state of what is termed biscuit, and are ready for use, unless they are required to be glazed, in which case they may be dipped into a semi-liquid composition of siliceous and other matters, ground
in water to the consistency of cream, and the surface of the articles which are so dipped becomes covered with a thin coating of the glazed composition, and then the articles are again put into saggers, and subjected to a second operation of firing in another kiln, the heat whereof vitrifies the composition and gives a glassy surface to the articles, all which is the usual course of making glazed earthenware or porcelain; but for articles formed by the new process, a suitable glazing composition is more usually applied within the saggers, into which the articles are put for the first firing, and the glazing is performed at the same time with the first burning, without any other burning being required. Or, in other cases, the composition of earthy materials which is chosen for the articles may be such as will become partially vitrified by the heat to which they are exposed in the kiln, and thereby external glazing is rendered unnecessary.

The great contraction which must take place in drying articles which have been moulded from clay in the moist state is altogether prevented, and consequently all uncertainty in the extent of that contraction is avoided. Tiles, tesselare, and other articles are now made by this machine; and very beautiful pavements are constructed, excelling the finest works of the Romans in form, in color, and in all the mechanical conditions.

THEBAINE. C_2H_3NO. One of the numerous alkaloids contained in opium.

THALDINE. C_3H_5N_3S. A curious alkaloid, formed by the action of sulphuric acid on sodium ammoniaca.

THORIUM or THORIUM. A rare metal found in the mineral thorite which contains about 57 per cent. of thorina, the oxide of this metal.

TIN PLATES. The affinity of iron for tin is much greater than is generally supposed. The point at which the metals cohere is no doubt an actual alloy; and advantage is taken of this by the manufacturers of articles for domestic use, made in iron, as bridle bits, common stirrups, small nails, &c. When the iron, whether wrought or cast, is perfectly clean and free from rust, and brought in contact with melted tin, at a high temperature, an alloy seems to be at once formed, protecting the iron from oxidation whilst the tin lasts. Many plans are used for tinning iron articles, of small size, by the manufacturers. One of the common methods of manufacturers of bridle bits and small ware, in South Staffordshire, is to clean the surface of the articles to be tinned, by steeping them for sufficient time in a mixture of sulphuric and hydrochloric acids, diluted with water, then washing them well with water, but taking great care they do not rust, at once placing them in a partially closed stoneware vessel, (such as a common bottle,) which contains a mixture of tin and hydrochlorate of ammonia. This vessel is then placed on a smith’s hearth, duly heated, and frequently agitated to secure the complete distribution of the tin over the iron. The articles, when thus tinned, are thrown into water to wash away all remains of the sal ammoniac: and lastly, cleaned in hot bran, or sawdust, to improve the appearance for sale.

The plans of cleaning and preparing the iron for tinning have undergone many changes in the past century. About 1720 the plan for cleaning was to scour the plates with sand and water, and file off the rough parts, then cover with resin, and dip them in the melted tin. About 1745 the plates were, after being cold rolled, soaked for a week in the lees of bran, which had been allowed to stand in water about ten days, to become, by fermentation, sufficiently acid, and then scoured with sand and water. In 1760 the plates were pickled in dilute hydrochloric acid before annealing, and cleaned with dilute sulphuric acid after being taken out of the bran lees. An improvement of great importance in this process was made about 1745; the inventor seems to have been Mr. Mosely, who carried on tin plate works in South Staffordshire. This invention was the use of the grease pot, and in this department little, if any, improvement has since been made. The plan was introduced into South Wales in 1747 by Mr. John Jenkins, and his descendants are still amongst the principal manufacturers in the trade. The process of cleaning and tinning at some of the best works now is as follows:—When the sheet iron leaves the plate mill, and after separating the plates, and sprinkling between each plate a little sawdust, the effect of which is to keep them separate, they are then immersed, or, as technically termed, “pickled,” in dilute sulphuric acid, and after this placed in the annealing pot, and left in the furnace about 24 hours; on coming out, the plates are passed through the cold rolls; after passing the cold rolls, the plates seem to have too much the character of steel, and are not sufficiently ductile; to remedy this they are again annealed at a low heat, washed in dilute sulphuric acid, to remove any scale of oxide of iron, and scoured with sand and water; the plates in this state require to be perfectly clean and bright, and may be left for months immersed in pure water without rust or injury; but a few minutes’ exposure to the air rusts them. With great care to have them perfectly clean, they are taken to the stow, fig. 652, being a section through the line k k of the plan, fig. 653. Taken from right to left,

1 represents the Tinman’s pan.
2 the Tin pot.
3 “ the Washing or dipping pot.
4 represents the Grease pot.
5 " the Cold pot.
6 “ the List pot.

The tinman’s pan is full of melted grease: in this the plates are immersed, and left there until all aqueous moisture upon them is evaporated, and they are completely covered with
the grease; from this they are taken to the tin pot, and there plunged into a bath of melted tin, which is covered with grease; but as in this first dipping the alloy is imperfect, and the surface not uniformly covered, the plates are removed to the dipping or wash pot; this contains a bath of melted tin covered with grease, and is divided into two compartments. In the larger compartments the plates are plunged, and left sufficiently long to make the alloy complete, and to separate any superfluous tin which may have adhered to the surface; the workman takes the plate and places it on the table marked n on the plan, and wipes it on both sides with a brush of hemp; then to take away the marks of the brush, and give a polish to the surface, he dips it in the second compartment of the wash pot. This last always contains the purest tin, and as it becomes alloyed with the iron it is removed on to the first compartment, and after to the tin pot. The plate is now removed to the grese pot (No. 4); this is filled with melted grease, and requires very skilful management as to the temperature it is to be kept at. The true object is to allow any superfluous tin to run off, and to prevent the alloy on the surface of the iron plate cooling quicker than the iron. If this were neglected the face of the plate would be cracked. The plate is removed to the cold pot (No. 5); this is filled with tallow, heated to a comparatively low temperature. The use of the grease pots, Nos. 4 and 5, is the process adopted in practice for annealing the alloyed plates. The list pot (No. 6) is used for the purpose of removing a small wire of tin, which adheres to the lower edge of the plate in all the foregoing processes. It is a small cast-iron bath, kept at a sufficiently high temperature, and covered with tin about one-fourth of an inch deep. In this the edges of the plates are dipped, and left until the wire of tin is melted, and then detached by a quick blow on the plate with a stick. The plates are now carefully cleaned with bran to free them from grease. Lastly, they are taken to the sorting room, where every plate is separately examined and classed, and packed in boxes for market as hereafter described.

The tests of quality for tin plates are—ductility, strength, and color. To obtain these, the iron must be of the best quality, and the manufacture must be conducted with proportionate skill. This necessity will explain to some extent the cause why nearly all the improvements in working iron during the past century have been either originated or first adopted by the tin-plate makers; and a sketch of the processes used at different times, in working iron for tin plates, will be, in fact, a history of the trade.

The process of preparing the best or charcoal iron seems to have undergone but little change from 1720 to 1807. The finery, the chafery, and the hammer were the modes of bringing the iron from the pig to the state of finished bars. The finery was of the exact form of the figs. 654, 655, 656, but less in size than those now used. The chafery or hollow fire was, in fact, the same as the present smiths' forge fire, but on a larger scale; and the "hollow" or chamber, in which the bloom was heated, was made by coking the coal in the centre with the blast, and taking care not to disturb the mass of coal above, which was used to reverberate the heat produced. Both the finery and chafery were worked by blast.

The hammers were of two descriptions: the forge hammer, a heavy mass for shaping the blooms, and the tilt hammer, much lighter and driven quicker, for shaping the bars.

The charge for the finery was about 1½ cwt. of pig iron: this, under the first process, was reduced to 1⅔ cwt. It was, when ready, put under the forge hammer, and shaped into
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a "bloom," about 2 feet long and 5 inches thick; this was then heated in the chafery, and under the tilt hammer drawn out to a "bar," 3 to 4 inches wide, and half inch thick.

The manufacture up to this point, until a recent period, was carried on by the iron masters, and the iron in this state was sold under the name of "tin bars" to the plate makers. The average price for these bars, from 1789 to 1810, was £21 per ton. The sheet and cold rolls were then in use nearly as at the present time.

In 1807, Mr. Watkin George, whose position had been established as one of the first engineers of his time, by the erection of the great water wheel and works at Cyfarthfa, removed to Pontypool, and undertook the remodelling of the old works there. He clearly saw that the secret of the manufacture was to produce the largest possible quantity with the least possible machinery and labor. His inventions, to this end, worked a complete change in the trade. His plans were: to first reduce the pig iron in a finery under coke, and then bring this "refiners' metal" (so termed) into the charcoal finery. The charcoal finery was built as shown in figs. 654, 655, and 656; fig. 654 being a front elevation, fig. 655 a horizontal, and fig. 656 a vertical section.

A charge of 3 cwt. of iron was used in this, and as it became malleable it was reduced under the hammer to what he termed a "stamp:" this was a piece of iron about 1 inch thick, and of any shape horizontally. It was next broken in pieces of a convenient size, and about 84 lbs. were "piled" on a flat piece of tilted iron, with a handle about 4 feet long. This rough shovel, or holder, was called

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Note: The text includes illustrations and diagrams for the descriptions of the finery and hammering processes.
TIN PLATES.

the "portal," or the "staff." To reheat this "pile" in the chafery would be a work of great cost and difficulty, and the brick hollow fire (as shown in figs. 657, 658, 659, 660, 661, and 662; figs. 657 and 658 being elevations, and figs. 659, 660, 661, and 662 sections) was invented. This is, the writer believes, one of the inventions which, although in work during the past fifty years, still points to very great improvements in the manufacture of iron. It is in substance the plan of using the gases produced by the decomposition of fuel for the working of iron.

The charcoal finery is also worked by the use of the gases to a much greater extent than is generally known. The workman sends his blast directly into the mass of iron, and the charcoal seems to be simply the means by which he is better enabled to manipulate the iron in the finery, and keep it covered, so as to revive the oxidized metal, and thus prevent waste. A few hours spent with any intelligent workman at the side of his charcoal finery would show the wasteful and expensive character of the so-called new schemes for con-
verting cast into wrought iron by the use of air alone. The late belief in these schemes, by men of high repute and practical knowledge in the trade, is a direct proof of the deficiency in knowledge of exact science, as at present applied to the manufacture of iron.

The pile was now placed in the hollow fire, and brought to a soft welding or washing heat—again hammered out to "slabs" 6 inches wide and three quarters inch thick; these were reheated, cut up, and afterward passed through rolls, reducing them to "bars" 6 inches by half inch. These were known in the trade as "hollow fire iron" or "tin bars." The result of Mr. Watkin George's improvements was to reduce the cost and double the production with the same outlay in machinery. All the tin plates made at this time had the great defect of a rough and smooth side. In the year 1820, Mr. Win. Daniell (a gentleman still living, and for whose invention the trade is and will be under great obligation) found a mode to remedy this defect. Himself a maker of tin bars and plates, he had observed that the smooth side of the plate was always that corresponding to the flat part of the "portal," or "staff;" he at once, having ascertained this cause, remedied the defect by hammering out the pile, notching it, and doubling it over, so that the tilted blade of the "staff" was on the top as well as the bottom of the pile. This was the invention of "tops and bottoms," and the writer need not remind practical men of the immense sums made by this discovery during the past thirty-seven years.

Another improvement since 1807 is the use of the running-out fire: it is still adopted in only a few works. This is represented by figs. 663, 664, and 665. Fig. 663 is a front elevation; fig. 664 a horizontal section; and fig. 665 a vertical section. This process saves waste of heat and labor, by running the refined metal at once into the charcoal finery.
The "tin bars" before referred to, 6 inches by half inch, are heated and run through
rollers until they form a sheet of sufficient width; this sheet is then doubled and passed
through the rolls, and this repeated until this sheet is quadrupled,—the laminae are then
cut to size, and separated as before described. The writer asks careful attention to the
fact that the last part of the rolling is done when the iron is nearly cold. These sheets
are next annealed, and were formerly bent separately by hand, into a saddle, forming two
sides of a triangle, thus 

The plates should be now free from rust or scale, and are then passed cold through the
chilled rolls; this last process is most important, as the ductility and the strength and color
of the tin plate depend upon this; at this point bad iron will crack or split, and any want
of quality in the iron, or skill in the manufacture, will be shown.

A great improvement in the process of annealing was made in 1829 by Mr. Thomas
Morgan: the plates were piled on a stand, and covered with a cast-iron box, now termed an
"annealing pot;" in this they were exposed to a dull red heat in a reverberatory furnace

for 24 hours. This annealing pot with its stand is represented by fig. 666, in plan and
vertical section.

A very important invention in the manufacture of iron for tin plates, and which is yet
only partially carried out, was made by Mr. William Daniell in 1845. About 2½ cwt. of
refined metal is placed in the charcoal finery; this is taken out in one lump, put under
the hammer and "nobbled," then passed at once through the balling rolls, and reduced to
a bar 6 inches square and about 2 feet 6 inches long. This bar is either cut or sawed off
in pieces 6 inches long, and these rolled endways to give a bar about 6 inches wide, 2½
inches thick, and 12 inches long, and in this state the inventor calls it a "billet." This is
heated in a small balling finery and rolled down to a bar one quarter inch thick and eleven
inches wide, and will be about six feet long. This is taken at once to the tin-plate mill,
and the process saves great expense in fuel and machinery.

By the old method of annealing, a box of tin plates required about 13 lbs. of tin. This
is now done with about 9 lbs. for charcoal and 8 lbs. for coke plates.

In referring to tin plates the standard for quotation is always taken as 1 cwt. per 100 lbs.
(Comm., No. 1.) This is a box containing 225 plates, which should weigh exactly 112 lbs.

One of the great items of expense in the manufacture of best iron, as before described,
is the cost of charcoal for the finery. This limits at present the production of iron made
by these means; but the superior quality of iron made in the charcoal finery is always ad-
mitted. About 1850 the attention of the writer was directed to the use of a substitute for
charcoal in the finery. Careful thought and experiment led him to the conclusion that some
coals could be charred in such a way as to produce a mechanical structure analogous to
charcoal, and at the same time, when deprived of sulphur, might be used in the finery.
These experiments resulted in the manufacture of a substance the writer names "charred
coalt." This material has been worked at several of the principal manufactories in South
Wales, and declared equal in every respect to charcoal. Some tin plates made by this
process were shown at the Great Exhibition in 1851; as also the charred coal used in the
finery. (See the J. Iron's Reports, &c.) The quality of the plates was admitted as equal to
the best charcoal.

The preparation of the "charred coal" is very simple. The coal is first reduced to
small, and washed by any of the ordinary means: it is then spread over the bottom of a
reverberatory finery to a depth of about 4 inches: the bottom of the furnace is first raised
to a red heat. When the small coal is thrown over the bottom a great volume of gases is
given off, and much ebullition takes place: this ends in the production of a light spongy
mass which is turned over in the finery, and drawn in about one hour and a half. To
completely clear off the sulphur, water is now freely sprinkled over the mass until all smell
of the sulphurated hydrogen gas produced ceases. The result is "charred coal." The
quantities of "charred coal" hitherto produced have been made on the floor of an ordinary
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coke oven, whilst red hot, after drawing the charge of coke. The following analysis of the coal from which this "charred coal" is made, is extracted from the "Report on the Coals Suited to the Steam Navy" by Sir H. de la Roche and Dr. Playfair:

<table>
<thead>
<tr>
<th>Analysis</th>
<th>81:26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>6:31</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>77</td>
</tr>
<tr>
<td>Oxygen</td>
<td>9:66</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1:8i</td>
</tr>
<tr>
<td>Ash</td>
<td>2:04</td>
</tr>
</tbody>
</table>

102:20

Some points of great practical value may be elicited from this description of the manufacture of iron for tin plates. The stamp iron is highly crystalline, and falls to pieces under the hammer unless cautiously handled. The pile itself, after heating, is also crystalline and brittle; but after passing through the rolls it becomes less crystalline. When reduced to a sheet it is still less crystalline and more ductile; but after passing the cold rolls all the crystalline character is apparently destroyed, and it becomes a homogeneous mass, and very ductile, hard, and tough. The hammering and rolling appear to alter the structure of the iron, and, instead of allowing the atoms to arrange themselves in crystals, to bring them into a homogeneous or amorphous mass, which is then held together by the law of cohesion, and is more dense and closer than when crystallized. In practice this principle is constantly used. Every smith knows the practical result of what is termed "hammer hardening."

The coating of iron and zinc, by Mr. Morries Stirling's patent process. For this purpose the sheet, plate, or other form of iron, previously coated with zinc, either by dipping or by depositing from solution of zinc, is taken, and after cleaning the surface by washing in acid or otherwise, so as to remove any oxide or foreign matter which would interfere with the perfect and equal adhesion of the more fusible metal or alloy with which it is to be coated, it is dipped into melted tin, or any suitable alloy thereof, in a perfectly fluid state, the surface of which is covered with any suitable material, such as fatty or oily matters, or the chloride of tin, so as to keep the surface of the metal free from oxidation; and such dipping is to be conducted in a like manner to the process of making tin plate or of coating iron with zinc. When a fine surface is required, the plates or sheets of iron coated with zinc may be passed between polished rolls (as already described) before and after, or either before or after they are coated with tin or other alloy thereof. It is preferred in all cases to use for the coating pure tin of the description known as grain tin.

Another part of the invention consists in covering either (wholly or in part) zinc and its alloys with tin, and such of its alloys as are sufficiently fusible. To effect this, the following is the process adopted:—A sheet or plate of zinc (by preference such as has been previously rolled, both on account of its ductility and smoothness) is taken, and after cleaning its surface by hydrochloric or other acid, or otherwise, it is dried, and then dipped or passed in any convenient manner through the melted tin, or fusible alloy of tin. It is found desirable to heat the zinc, as nearly as may be, to the temperature of the melted metal, previous to dipping it, and to conduct the dipping, or passing through, as rapidly as is consistent with thorough coating of the zinc, to prevent as much as possible the zinc becoming alloyed with the tin. It is recommended also that the tin or alloy of tin should not be heated to a higher temperature than is necessary for its proper fluidity. The metal thus coated, if in the form of sheet, plate, or cake, can then be rolled down to the required thickness; and should the coating of tin or alloy be found insufficient or imperfect, the dipping is to be repeated as above described, and the rolling also, if desired, either for smoothing the surface or further reducing the thickness.

Another part of the invention consists in coating lead or its alloys with tin or alloys thereof. The process is to be conducted as before described for the coating of zinc, and the surface of lead is to be perfectly clean. The lead may, like the zinc, be dipped more than once, either before or after being reduced in thickness by rolling.

Lead and its alloys may also be coated with tin or its alloys of greater fusibility than the metal to be coated, as follows:—The cake, or other form to be coated, is to be placed as soon after casting as may be in an iron, gun metal, or other suitable mould; or, if this cannot be conveniently done, the surfaces are to be cleansed and prepared for the reception of the coating metal, either by previously tinning the surface, or by applying other suitable material to facilitate the union, as heretofore practised. At one end of the mould are to be attached chambers, of more than sufficient capacity to contain the quantity of metal to be used for coating, which may with advantage form an integral part of the mould, or such chamber may surround the mould, and by one or more sluices or valves in such chamber or chambers, the melted metal is to be allowed to run on to the surface of the metal to be coated, when the metal is to be coated on one side only. When it is intended to coat the metal on both sides, the vertical position will be found convenient, and the coating metal is

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to be poured into a chamber or chambers attached to the mould, and to be introduced into the lower part of the mould by opening a sluice or valve, sufficient space being left on each side of the cake or other form to allow of the coating being of the required thickness; the sluice or valve should be of nearly the width or length of the cake or other form, and the melted metal should be allowed to flow into the bottom of the mould. The surface of the plate or cake ought to be smooth and true, and the mould, if horizontal, to be perfectly so, and if upright, quite perpendicular, so as to insure in either case an equal footing. The surface of the lead should also be clean, and it will be found advantageous to raise its temperature to a point somewhat approaching the melting point of tin or of the alloy employed for coating, as by this means the union of the two metals is facilitated. It is recommended also, that a somewhat larger quantity of the tin or alloy than is necessary for the coating of the lead or other metal, or alloy, should be employed, and that when the requisite thick-ness of coating has been given, the flow of the coating metal be stopped, as by this means the inclusions on the surface of the tin will be prevented passing through the molten on to the surface of the cake; the chamber or chambers should be kept at such temperature as to insure the proper fluidity of the coating metal. Zinc and its alloys may in like manner be coated with tin and its alloys, by employing a like apparatus to that just described for coating lead and its alloys, and it constitutes a part of this invention thus to coat zinc. The coating of zinc with tin, however, is not claimed, that having been done by pouring on tin.

TUBES. The manufacture of iron tubes for gas, water, and other purposes has become one of extreme importance. Mr. Russell of Wednesbury patented a process which has been carried out on a very large scale. In this process plate iron, previously rolled to a proper thickness, is cut into such strips or lengths as may be desirable, and in breadth corresponding with the width of the tube intended to be formed. The sides of the metal are thinned up with swages in the usual way, so as to bring the two edges as close as possible together. The iron thus bent is then placed in an air or blast furnace, and brought to a welding heat, in which state it is withdrawn and placed under the hammer. Fig. 667, A, is the anvil having a block or bolster, with a groove suited to and corresponding with a similar groove, n, in the face of the block. c is a wheel with projecting knobs, which, striking in succession upon the iron-shod end of the hammer shaft, causes it to strike rapidly on the tube. In this process the tube is repeatedly heated and hammered, until the welding is complete from end to end. A mandrel may be inserted or not during this operation. When the edges of iron have been thus thoroughly united, the tube is again heated in a furnace, and then passed through a pair of grooved rollers similar to those used in the production of rods, fig. 668. Suppose a tube, P, to be passing through these rollers, of which fig. 669 represents a cross section, immediately upon its being delivered from the groove it receives an egg-shape core of metal fixed upon the extremity of the rod, r, over which the tube sliding on its progress, the inside and outside are perfected together. Mr. Cort patented a similar process for the manufacture of gun barrels.

TUPA. A volcanic product. See Mortar, Hydraulie, vol. ii.

TUNGSTEN. (Tungstine, Fr.; Wolframium, Ger.) Symbol, Ts or W. Its name is derived from the principal mineral from which it is obtainable. Tungsten, Swedish, tung, heavy, sten, stone, or Wolfram, German. This metal was discovered by the brothers De Luyart, about 1784, shortly after the discovery of tungstic acid by Scheele, from whom it is sometimes called Scheelitum. It is never found in the native state, but is produced by a variety of processes. First, and most easily, by mixing the dried and finely-powdered tungstate or bitungstate of soda with finely-divided charcoal, such as lampblack, placing the mixture in a crucible lined with charcoal, covering it with charcoal in powder, and then exposing the whole to a steady red heat for two or three hours. On removal of the crucible and cooling it, a porous mass is found, from which the soda is removed by solution in water, and the unconserved carbon is separated by washing it off. The metal being left as a bright, glistening, blackish-gray metallic powder. It may also be obtained by treating tungstic acid in a similar manner, or by exposing the acid at a bright red heat, in an iron or glass tube, to a current of hydrogen gas. Tungsten is one of the heaviest metals known,
TUNGSTEN.

its specific gravity being 17.29 to 17.6. It requires such a very high temperature for fusion that it has never yet been obtained in mass; more commonly as a fine powder, but sometimes in small grains. It is not magnetic. It is very hard and brittle. Alone it has not been rendered available for any useful purpose, but it has lately been employed for the manufacture of certain alloys. Tungsten is comparatively a rare substance, and is remarkable for the very limited extent to which in nature it is found to have been mineralized by combination with other substances. In none of these does it exist as a salifiable base, but as an acid, as in wolfram, Scheelite, yttrontantalite, and the tungstate of lead.

The most common ore of this metal is wolfram, known also to the Cornish miner as cal or calien, and gossan. It is most commonly found associated with tin ores, which contain besides the black oxides of tin or cassiterite, the metallic minerals, arsenical iron, copper, lead, and zinc sulphides; but its peculiarly characteristic associate is the metal molybdenum, for the most part mineralized as a sulphide. This metal is remarkable in connection with tungsten as producing isomeric compounds, and as having both its equivalent and its specific gravity equal to about one half that of tungsten, they being respectively as follows: - equivalents, Ts, 96; Mo, 48; sp. gr. Ts, 16.22; Mo, 8.615.

Amongst miners wolfram has the reputation of being an abundant mineral, but on close inquiry it is found to be comparatively rare, scart, specular, and other iron ores, and gossan being commonly mistaken for it. From its association with tin ores, it has been until lately the source of great loss to the miner, as it was found quite impossible to separate it even to a moderate extent from the ore in consequence of its specific gravity, 7.1 to 7.4, being so near to that of black tin, 6.3 to 7.0.

Pryce, in his Mineralogia Cornubensis, 1778, says: "After the tin is separated from all other impurities by repeated dilutions, there remains a quantity of this mineral substance, (gal,) which being of equal gravity cannot be separated from the tin ore by water, therefore it impoverishes the metal and reduces its value down to 8 or 9 parts of metal for twenty of mineral, which without its brood, so called, might fetch twelve for twenty." This description of tin ores containing wolfram was still applicable until a very recent period, when a new process was invented by Mr. Robert Oxland, of Plymouth, and by him successfully introduced at the Drake Wells Tin Mine, at Gunnis Lake, on the banks of the Tamar, where it has been continued in operation ever since. At this mine, although the tin ore raised was of excellent quality, in spite of all that could be done by the old processes, it was left associated with so much wolfram that the ore fetched the lowest price of any mine in Cornwall.

At the time of the introduction of the process the greater portion of the ore was sold for £12 per ton. The improvement effected by it was so great that the same sort of ore sold for £50 per ton. The Drake Wells ores are now known as the best of the mine ores in Cornwall.

The process consists in taking tin ores mixed with wolfram, dressed as completely as possible by the old process, and having ascertained by analysis the quantity of wolfram contained therein, then mixing therewith such a quantity of soda ash of known value as shall afford an equivalent of soda for combination with the tungstic acid of the wolfram, which is the tungstate of iron and manganese; the object of the process being by calculation to convert the insoluble tungstate of iron and manganese into the soluble tungstate of soda, leaving the oxides of iron and manganese in a very finely-divided state and of low specific gravities, so that they can be easily washed off with water.

The mixture, in charges of five to ten cwt., is roasted in a reverberatory furnace on a cast-iron bed of the construction shown in fig. 670 and 671. The use of the cast-iron bed is attended with considerable economy in the consumption of fuel, and it is admirably well adapted for the calcination of the raw ores, for the evolvement of the sulphur and arsenic contained in them; but it is especially necessary instead of fire brick or tile, to avoid the loss which would accrue from the reaction of the soda ash on the silica of the brick, and the formation of soda silicate of tin which would consequently take place. The mixture is introduced to the bed through a hole in the crown of the furnace; from a side door it is equally distributed over the bed,
and from time to time it is turned over by the furnace man until the whole mass is of a dull red heat, emitting a slight hissing sound, and in an incipient pasty condition. In successive quantities the charge is then drawn through a hole in the bed of the furnace into the \textit{wrinkle} or arch beneath, whence it is removed to cisterns, in which it is lixiviated with water, and the tungsstate of soda is drawn off in solution. The residuary mass left in the cisterns,—the whole of the soluble matter having been washed out,—is removed to the burning-house floors, and is there dressed over again in the usual manner, the final product of the operations being very nearly pure black oxide of tin. The liquid obtained is either evaporated sufficiently for crystallization when set aside to cool, or is at once dried down to powder. The crystals of tungsstate of soda thus obtained are colorless, translucent, of a beautiful pearly lustre, having the form of rhombic prisms or of four-sided laminae. The composition of the crystallized and of the anhydrous tungsstate of soda is as follows:
\[
\begin{array}{ccc}
\text{Anhydrous} & \text{Crystalline} \\
\text{Soda} & 20.83 & 18.44 \\
\text{Tungstic acid} & 79.37 & 79.92 \\
\text{Water} & 0.00 & 10.64 \\
\hline
100.00 & 100.00
\end{array}
\]

It has been proposed to use this substance as a mordant for dyeing purposes, as a source of supply of metallic tungsten for the manufacture of alloys, for the manufacture of the tungsstates of lime, barytes, and of lead to be used as pigments; and still more recently it has been found to be valuable, and preferable to any other substance, for rendering fabrics not inflammable, so as to prevent the terrible accidents constantly occurring from the burning of ladies' dresses. For this purpose a patent has lately been obtained by Messrs. Vermann and Oppenheim.

For the manufacture of metallic alloys a patent has been obtained by Mr. R. Oxland, as a communication from Messrs. Jacob and Koehler. Steel of very superior quality, manufactured under this patent, is now coming extensively into use in Germany. It is prepared by simply melting with cast steel, or even with iron only, either metallic tungsten, or preferably, what has been termed the native alloy of tungsten, in the proportion of two to five per cent. The steel obtained works exceedingly well under the hammer. It is very hard and fine grained, and for tenacity and density is superior to any other steel made. The native alloy is obtained by exposing to strong heat in a charcoal-lined crucible a mixture of clean powdered wolfram with fine carbonaceous matter. A black, steel-grey metallic spongy mass is obtained resembling metallic tungsten. The composition of the alloy is shown in the following statement of the composition of wolfram:

\[
\begin{array}{ccc}
\text{Tungstic acid} & \text{Oxide of iron} & \text{Oxide of manganese} \\
78.25 & 17.75 & 100 \\
19.06 & 5.07 & \text{Manganese} = 100 \\
\text{Oxygen} & \text{Oxygen} & 1.71 = 25.84 \\
\hline
125.84 & 125.84 & \text{Manganese}
\end{array}
\]

The tungsstate of soda is used in dyeing; metallic tungsten, or native alloy, is also used for the manufacture of paekfong or Britannia metal, by alloying with copper and tin. By these useful applications this metal has already become a desideratum, which only a few years since was regarded as one of the most deleterious associates of tin ores, and the only one that was perfectly unmanageable.—R. O.

\textbf{TURBINE.} Although the horizontal water wheel has been known and employed under various forms from the highest antiquity, and has latterly been improved by Fourneyron, Fontaine, Jouval, and others, so as to rank among the most perfect of hydraulic motors, it has only recently been applied to mining uses, (pumping, loading, &c.,) and where so employed its success can scarcely be said to be yet decided. The failures may be attributed to the following causes. First: The plan of causing the water to flow simultaneously through all the buckets, necessitates the use of wheels of small dimensions, making a very great number of revolutions per minute, and thus requiring a considerable train of intermediate gear to reduce the speed to the working rate. Second: The complex nature of
the ring sluices employed between the guide curves and the mouths of the bucket, renders them uncertain in action, and from their small dimensions liable to be easily choked by any mechanical impurities in the water; and lastly, the lubrication of the foot spindle of the vertical wheel, revolving at very great velocity, is attended with considerable difficulty and inconvenience, especially where the engine room is at a considerable distance below the surface of the earth, and it is requisite, as in the case of pumping wheels, to keep the machinery in action continuously for long periods of time. The form of wheel of which a notice is here appended, was introduced into the Saxon mines about the year 1849 by Herr Schwamkrug, inspector of machinery at the Royal Mines and Smelting Works at Freyberg, and since that time several have been introduced for pumping, winding, driving stamp-heads, &c. The example selected for illustration was built to take the place of two overshot water-wheels, employed in pumping water at the mine "Churprinz Friedrich August;" it differs from the usual form of turbine in having the wheel placed vertically, and in having the water supplied through a small number of guide curves near the lowest part. In this latter respect it resembles the tangential turbine of General Poncelet, with this difference, that the water flows from the inner to the outer circumference, instead of the reverse way, as is the case in Poncelet's wheel. The construction of the wheel is as follows: a, fig. 672, is the tubular axle of cast iron which carries the seating for the arms s, which is similar to that usually used for large water-wheels; to the ends of the arms is attached the wheel w, which is formed of two brags or shroudings of sheet iron, each 13 inches deep, measured radially, and of a total height of 10 feet 2 inches; these two rings are maintained at a distance of 6 inches apart, by means of 44 sheet-iron buckets of the form shown in the smaller detailed figure, fig. 673; the driving water is admitted through the pressure pipe y, in which is placed the admission throttle f, and turned through a pipe of rectangular section (shown in the smaller figure) into the sluice box s, which contains the two guide curves v, v', which are movable about the centres e, e', by means of the levers l, l', by means of these guide curves when fully opened, as shown in the figure; the water is admitted into the buckets in two parallel streams of jets of 5½ inches in breadth, and 1½ inches in thickness; the power is transmitted from the axle of the wheel by a pinion with 28 teeth, which draws the large toothed wheel x, which acts on a third shaft carrying the pump
eranks. The wheel is constructed to work under a head of 147 feet, and makes about 130 revolutions per minute, with a maximum quantity of 550 cubic feet of water, equal to nearly 175 horse power. A series of dynamometrical experiments on a wheel of similar construction of 7 feet 9 inches in diameter, with a discharge varying from 39 to 134 cubic feet, with a head of 105 feet, gave an available duty of from 58 to 79 per cent., the number of revolutions varying from 112 to 148 per minute.

In conclusion it may be remarked that the vertical turbine may be employed with advantage where the available fall of water is too great to be employed on a single overshot water-wheel; and although a less perfect machine than the water-pressure engine, it is of simpler construction, and may be preferred where, from the hardness or yielding nature of the rock, it becomes difficult to construct large machine rooms or wheel pits underground. In practice it is found necessary to surround the wheel with a casing of wood, in order to prevent the affluent water being projected to a distance from centrifugal action.

TURKEY RED is the name given to one of the most beautiful and durable of known dyes. The art of dyeing cotton with this color seems to have originated in India. In his Philosophy of Permanent Colors, Bancroft has given a detailed account of the process as practiced in that country, and this process will be found to agree in all essential particulars with that pursued by the Turkey-red dyers of Europe, except that in India the chaya root is employed as the dyeing material in the place of madder. In the middle ages the art was practised in various parts of Turkey and Greece, especially in the neighborhood of Adrianople, and hence this color is often called Adrianopelian. Even as late as the end of the last century the manufacture of Turkey-red yarn seems to have been extensively carried on at Adria and other places in the neighborhood of Larissa. An interesting account of its manufactures and trade of this then flourishing district, by Felix, will be found in the Annales de Chimie, t. xxi. 1799. About the middle of the last century the art of Turkey-red dyeing was introduced into France by means of dyers brought over from Greece. The French were also the first to dye pieces with this color, the art having previously been applied merely to the dyeing of yarn. The first establishments for dyeing this color in Great Britain were founded and conducted by Frenchmen. At the present day Turkey-red dyeing is carried on in various parts of France and Switzerland, at Elberfeld in Germany, in Lancashire, and at Glasgow.

Turkey-red dyeing is essentially distinguished from other dyeing processes by the application previous to dyeing of a peculiar preparation consisting of fatty matter combined with other materials. Without the use of oil or some fatty matter it would be impossible to produce this color, of which indeed it seems to form an essential constituent. If the color of a piece of Turkey-red cloth is examined, it will be found to consist of red coloring matter and fat acid, combined with alumina and a little lime. The coloring matter thus obtained is so little contaminated with impurities as to appear on evaporating its alcoholic solution in yellowish-red crystalline needles. What part the fat acid plays, whether it merely serves to give to the compound of coloring matter and alumina the power of resisting the action of the powerful agents used after the operation of dyeing, or whether it also modifies and imparts additional lustre to the color itself, is quite unknown. The formation of this triple compound of coloring matter, fat acid, and alumina, seems at all events to be the final result which is attained. Nevertheless, this apparently simple result can only be arrived at by means of a long and complicated process, each step of which seems to be essential for its final success. The details of the process vary considerably both in their nature and number, in different countries and different dyeing establishments. They may however be described in general terms as follows:

The goods, after being passed through a soap bath or weak alkaline lye, are oiled. For this purpose a mere impregnation with oil would not be sufficient. The oil must be mixed with a solution of carbonate of potash or soda, to which there is often added a quantity of sheep or cow dung, the ingredients being well mingled, so as to form a milky liquid or emulsion. Olive or Gallipoli oil is the kind generally used, and an impure, mucilaginous oil is preferred to one of a finer quality. Drying olls are not adapted for the purpose. In this liquid the goods are steeped for a short time, so as to become thoroughly impregnated with it. In the case of pieces the liquid is generally applied by means of a padding machine. After being taken out of this liquid the goods are often left to lie for some days in heaps, and if the weather is fine, they are then exposed on the grass to the action of the air; otherwise, they must be hung up in a hot stove. This process of steeping and exposing to the air is repeated a number of times, until the fabric is thoroughly impregnated with fatty matter. During this part of the process there can be no doubt that the oil undergoes a partial decomposition and oxidation, so as to become capable of uniting, on the one hand, with the vegetable fibre, and, on the other hand, with the coloring matter, with which it is subsequently brought into contact. The dung, by inducing a state of fermentation among the ingredients, probably promotes the decomposition of the oil into fatty acid and glycerine, and the alkali serves to convey the fatty acid into every part of the fabric, and to assist in its oxidation on exposure to the air. The process of oxidation which takes place is sometimes so active as to
produce spontaneous combustion of the goods in the store. It might be supposed that by previously saponifying the oil, impregnating the goods with the soap, and, after sufficient exposure, decomposing the latter by means of an acid, the same object might be more easily attained than by the long process usually employed. This is, however, not the case, which proves that we are still ignorant of the exact chemical nature of the change which takes place during the oiling process. The supposition formerly entertained, that the effect of the oiling consisted in a so-called *animalisation* of the vegetable fibre, is quite untenable. In some establishments, the goods, after being oiled and sooted, are passed through a bath of very dilute nitric acid, and then exposed to the air before being oiled again, the process being repeated after every oiling. The nitric acid is supposed to contribute to the oxidation of the oil. Several years ago a patent was taken out by Messrs. Mercer and Greenwood for preparing the oil, previous to its being applied to the cotton, by treating it with sulphuric acid, and then with chloride of soda, but their invention, though apparently of some importance, has not generally been adopted by Turkey-red dyers.

After being oiled, the goods are steeped for some hours in a weak tepid solution of carbonate of potash or soda. This operation, which is called by the French *dépâtreage*, serves to remove the excess of fatty acid, or that portion which has not thoroughly combined with the vegetable fibre. The liquid thus obtained is carefully preserved for the purpose of being mixed with the liquid used for the oiling of fresh goods, the quality of which it serves to improve.

To this operation succeeds that of galling and mordanting. The goods, after being washed, are passed through a warm solution of tannin, prepared by extracting galls or sumac with boiling water and straining, after which they are impregnated with a solution of alum, to which sometimes a little chalk or carbonate of potash is added, or with a solution of acetate of alumnia, prepared by double decomposition from alum and acetate of lead. Sometimes the alum is dissolved in the decoction of galls, and thus the two operations are combined into one. The goods, after being dried in the stove, passed through hot water containing chalk, and rinsed, are now ready to be dyed. It has been asserted that the galling is not an essential part of the process, that it merely serves to fix the alumina of the mordant, and may be dispensed with when acetate of alumina is used instead of alum. It is certainly difficult to conceive how it can permanently affect the appearance of the color, since the tannin of the galls is undoubtedly removed from the fibre during the subsequent stages of the process.

The dyeing is performed in the usual manner. The materials employed are madder, chalk, sumac, and blood, in various relative proportions. The heat of the dye bath is gradually raised to the boiling point, and the boiling is continued for some time. The part played by the chalk in dyeing with madder has been explained above. It was formerly supposed that the red coloring matter of the blood contributed in producing the desired effect in Turkey-red dyeing; but to the modern chemist this supposition does not appear probable. Nevertheless, it is certain that the addition of blood is of some benefit, though it is uncertain in what the precise effect consists. Glue is occasionally employed in the place of blood. Sometimes a second mordanting with galls and alum, and a second dyeing, is allowed to succeed the first mordanting and dyeing.

After being dyed the goods appear of a dull brownish-red color, and they must therefore be subjected to the brightening process, in order to make them assume the bright red tint required. For this purpose they are first treated with a boiling solution of soap and carbonate of potash or carbonate of soda, and then with a mixture of soap and muriate of tin crystals. This operation is usually performed in a close vessel under pressure. The alka- lies remove the brown coloring matters and the excess of fat acid contained in the color, and the tin salt probably acts by extracting a portion of the alumina of the mordant, and substituting in its place a quantity of oxide of tin, which has the effect of giving the color a more fiery tint. The last finish is given to the color by treating the goods with bran or with chloride of soda.

The chief objects which the Turkey-red dyer seeks to attain are, 1st, to obtain the desired effect with the least possible expenditure of time and material; 2d, to produce a perfect uniformity of tint in the same series of dyeings; and, 3d, to impart to his goods a color which, though perfectly durable, shall be fixed as much as possible on the surface of the fabric. The last point is one of importance in the case of calicos dyed of this color, since this kind of goods is much employed for the production of a peculiar style of prints, in which portions of the color are discharged, in order either to remain white or to be covered with other colors. And if the red dye is too firmly fixed, or too deeply seated, it becomes more difficult to discharge it. In this respect the art has in modern times attained to such a degree of perfection, that the interior of each thread of Turkey-red cotton will be found on examination to be perfectly white. This is particularly the case with the Turkey reds from the establishment of Mr. Steiner of Accrington, Lancashire, whose productions in this branch of the art of dyeing are also unrivalled for the brilliancy and purity of their color. See Madder and Calico Printing.—E. S.
UREA. This is one of the principal constituents of urine, being always present in it, but in variable quantities: the average quantity in healthy urine is about 14 or 15 parts in 1,000 of urine, but of course this varies from several circumstances, as in disease, drinking a large quantity of liquid, &c. The urine passed the first in the morning gives a fair estimate of the quantity of urea yielded by the urine of an individual. It seems to be the principal form in which the waste nitrogenous compounds of the body are eliminated from the system. It is very prone to decomposition when in contact with albumen, mucus, or any fermentable matter; and this is the cause of urine, which, when first passed, is generally slightly acid, becoming alkaline, and a precipitate being formed; the change being much more rapid in hot than in cold weather, the mucus, &c., beginning to ferment sooner. The urea is decomposed into carbonate of ammonia, water being at the same time assimilated.

$$\text{C}_2\text{H}_4\text{N}_2\text{O}_6 + 4\text{OH} \rightarrow 2(\text{NH}_4\text{CO}_3)$$


The carbonate of ammonia neutralizes the acid which keeps the phosphates in solution, and hence the precipitate.

In some diseases the quantity of urea in the urine amounts to 30 parts, and even more, in the 1,000 parts of urine.

It is interesting as being the first organic base which was made artificially. It was found that cyanate of ammonia, which has exactly the same ultimate composition as urea, when dissolved in water and boiled for some time, became completely changed, neither cyanic acid nor ammonia being detected by the ordinary test in the solution, and that it had in fact been converted by a molecular change into urea.

$$\text{NH}_4\text{CN}_2\text{O}_6 \rightarrow \text{C}_2\text{H}_4\text{N}_2\text{O}_6$$

Cyanate of ammonia. Urea.

Its presence in the urine is detected thus: evaporate a portion of the urine over a water bath to about one fourth of its bulk, and when cold add half its volume of pure nitric acid, when after a little time abundant crystals of nitrate of urea will be formed.

The quantity of urea in any sample of urine may easily be estimated by a process invented by Liebig. It consists in treating the urine with a standard solution of pernitrate of mercury. A copious white precipitate is formed, with liberation of nitric acid. As this acid prevents the further action of the nitrate, the urine is previously treated with a solution of two vols. of saturated baryta water, and one vol. of saturated solution of nitrate of baryta, which precipitates the phosphates, and the excess of baryta neutralizes the nitric acid as soon as it is liberated. The addition of the nitrate of mercury is continued until the last portion added causes a yellow binxido of mercury instead of a white precipitate. The quantity of urea present in a given sample of urine may thus be readily deduced from the quantity of the nitrate required to precipitate it completely, the solution of nitrate of mercury being so arranged that every 100 grains of it shall be equal to one grain of urea.

It is also to be noticed that no precipitate is formed in the presence of common salt; that therefore has to be also removed by addition of nitrate of silver before using the nitrate of mercury. By an ingenious application of this fact, the quantity of common salt in any sample of urine may also be determined by the same solution of nitrate of mercury. Urea when in solution acts as an alkali on test paper; it unites with acids forming salts, the nitrate and oxalate being the least soluble of them. Although urea is so easily decomposed, a pure solution of it may be kept a considerable time unchanged.—H. K. B.

V

VACUUM PAN. For a description of it, see Sugar.

VALUE. Two methods have been adopted for ascertaining the value of our exports; one by means of the official value, the other according to the declared value. In Lowe's Present State of England, (1822,) there is a very succinct and clear account of these methods, which is here extracted:

"The official value of goods means a computation of value formed with reference, not to the prices of the current year, but to a standard, fixed so long ago as 1696, the time when the office of Inspector General of the imports and exports was established, and a Custom-house ledger opened to record the weight, dimensions, and value of the merchandise that passed through the hands of the officers. One uniform rule is followed, year by year, in the valuation, some goods being estimated by weight, others by the dimensions, the whole without reference to the market price. [Worsteds stuffs are valued at £1 11s. 8d. the piece, according to MacGregor's Commercial Statistics.] This course has the advantage of exhibiting, with strict accuracy, every increase or decrease in the quantity of our exports."
VEGETABLE EXTRACT.

"Next as to the value of these exports in the market:—In 1798 there was imposed a duty of 2 per cent. on our exports, the value of which was taken, not by the official standard, but by the declaration of the exporting merchants. Such a declaration may be assumed as a representation of, or at least an approximation to, the market price of merchandise, there being on the one hand no reason to apprehend that merchants would pay a percentage on an amount beyond the market value, while on the other the liability to seizure afforded a security against undue valuation."

VEGETABLE EXTRACT. In offering anything new, more especially as connected with an art so long practised as that of brewing malt liquors, Mr. Hodge, whose patent we are about to describe, is fully aware that changes in old established methods are never received readily. It is, however, evident that there are certain points in the art attached in the production of malt liquors, which, if carried out on scientific principles, would be a great boon to the profession.

The present practice of first making an extract of malt, and then adding the hop-leaves to the wort in the copper, for the purpose of getting out their extractive matter (in a liquid already nearly to the point of saturation) is not in accordance with scientific principles.

It is a well-known fact that, without long boiling, the resin, lupuline, and tannic acid of the hops are not readily disengaged from the leaf; hence we find all brewers say that they like a good, long, sharp boil to make the beer keep well.

The two most antiputrefacient ingredients are the lupuline and tannic acid; but while the long boiling is going on to get these two ingredients liberated, the volatile oil, or that which gives the soothing principles as well as the aroma, to the ale, passes off into the atmosphere and is lost, so that the beer or ale has a nasty, rough, acid taste, somewhat like gentian root. The great question is? what are the constituents of wort liquor when drawn from the mash tun, what do we want to retain, and what to get rid of: The worts are composed of water, saccharine matter, starch in small quantity, albumen, and gluten. The saccharine matter is the only thing we want to retain, save its proper proportion of water. The other ingredients are nitrogenous, and liable to produce putrid fermentation.

Boiling of the worts is intended to coagulate the nitrogenous matter; two minutes will do this at 200° Fahr. What must now be effected is to bring these particles of coagulated matter into contact with the tanning, resinous, and lupuline properties of hop, rendering them insoluble; which chemical change prevents, in a measure, further decomposition for a time, until they are nearly all got rid of by fermentation or after precipitation.

There cannot be a doubt that boiling worts to a certain extent is necessary, but long boiling is decidedly injurious, as there must be a decomposition of the saccharine matter going on, as well as a reglutenization of the albumen and other compounds, unless these particles are immediately brought into contact with those properties of the hop to arrest it.

All these difficulties can be prevented by first making an extract of hop in a close digester, as is represented in the enclosed drawing, fig. 674. The most volatile properties can either be distilled over, or drawn off from the top, and added to the worts after they are cooled, and before fermentation. The keeping principle of the hop will then be drawn off in a strong decoction and added to the worts after they are allowed to boil a few minutes, when the particles of nitrogenous matter will be immediately changed, retaining the aroma and other delicate properties of the hop.

Hence the advantage of the separate extract of hop, in vessels where the temperature can be regulated to the greatest nicety, and where the air cannot come into contact to change the color of the liquid or lose the aroma.

Another advantage in this process is, not allowing the hop leaf to go into the wort, thereby saving one in every 30 barrels brewed, or 3 per cent. on all malt extract, which to some brewers would amount to £20,000 per annum.

Figs. 674, 1 and 2, (a and A,) are two digesters, which are supplied with water to the interior at 212° Fahr. This is admitted by the water-pipe passing through the hollow journal, and thence down the side pipe in the interior of the vessel below the perforated platform A. The hops are placed between these platforms a and a'. Steam is let on from the steam-pipe passing through the hollow journal, and into the steam-jacket c, c, c, which keep up the temperature of the mass at or above 212° Fahr., as may be deemed necessary; at the same time no steam is allowed to escape, hence the whole of the aromatic properties of the hop are preserved. This is done in two ways; first, by drawing off the top of the extract through the cock k, (this is added to the beer after it is cool;) or, the hop oil is distilled over by means of the heated r, and condenser a, and is run off through the cock n, fig. 675. The cover n is then drawn up by the chain and counter-weight. The extract is then drawn off through the bottom cock j, and is added to the boil. The perforated platform is removed, and the vessel, which swings on the trunnions, is turned upside down and the spent hops drop into a press. See Brewing.

Cooling.—The quicker worts are cooled down to the fermenting temperature after being boiled, the better. The less it is exposed to the action of the atmosphere the less liable it is to absorb oxygen, preventing acetous fermentation.
Rapid cooling to all brewers is of vital importance, for if wort be permitted to come into contact with the air during the time its caloric is given off, acidity must set in, especially in summer time.

The best method to cool worts is that which is shown and described in the drawing annexed, fig. 675.
VENTILATION OF MINES.

The worts are passed through copper tubes, thoroughly tiemed. Instead of passing a current of water round these tubes, a dew jet of water is sprinkled all over the outer surface, at the same time a current of cold air is brought into contact with the moist surface of the tube, so that as fast as the molecules of caloric are transmitted to the water through the metal tubes, they are blown away, giving place to others. By this process heat from liquids can be abstracted more rapidly than by any other. In fact, worts can be brought down to freezing temperature, although the water used may be 60° to 100° Fahr. Another great advantage is, that the quantity of water used is about one-half.

These tubes can be cleaned with a brush with perfect ease.

VENTILATION OF MINES. In our subterranean operations, especially where quantities of carbonic acid are constantly being produced by respiration and combustion, and where, especially in our coal mines, the workmen are constantly exposed to the efflux of explosive gas—light carburetted hydrogen—it becomes necessary to adopt the means of removing, as rapidly as possible, the air by which the miner is surrounded. See Struve's MIKE VENTILATOR.

Description of the Ventilating Fan at the Abercarn Collieries.—The mode of ventilation that is still generally used in the collieries of this country is the old furnace ventilation, where the required current of air through the mine is maintained by the rarefaction of the column of air in the ascending shaft, by means of a large fire kept constantly burning at the bottom of the shaft. In Belgium and France, on the contrary, this plan is almost superseded by the use of machinery to maintain the current of air; as the furnace ventilation, although possessing the important advantage of great simplicity and freedom from liability to derangement from disturbing causes, has some serious objections and deficiencies, and in some cases becomes so imperfect a provision for ventilation as to render a better system highly desirable and even necessary.

Mr. E. Rogers, having occasion to ventilate the workings in some extensive and very fiery coal seams recently won at Abercarn in South Wales, under circumstances where the furnace ventilation could not be applied, after carefully collecting every accessible information as to the ventilating machines used in Great Britain and on the Continent, came to the conclusion that a plan of machine proposed for the purpose some years since by Mr. James Nasmyth would be the most suitable and effective. After consultation with Mr. Nasmyth, it was resolved to test the principle and plan by actual practice; and the ventilating fan described was made at Patricroft by Mr. Nasmyth, and is erected at the Abercarn Collieries.

The general arrangements of the top of the shaft and the ventilating fan are shown in figs. 676 and 677. Fig. 678 is a side elevation of the fan and engine, to a larger scale; and fig. 677 a vertical section of the fan.
VENTILATION OF MINES.

The fan A, *fig. 677*, is 13½ feet diameter, with 8 vanes, each 3 feet 6 inches wide and 3 feet long. It is fixed on a horizontal shaft, b, 8 feet 7 inches in length from centre to centre of the bearings, which are 9 inches long by 4½ inches diameter. The vanes are of thin plate iron, and carried by forked wrought-iron arms secured to a centre die, c, fixed upon the shaft b. The fan works within a casing d e n, consisting of two fixed sides of thin wrought plate, entirely open round the circumference and connected together by stay rods; the sides are 3 inches clear from the edges of the vanes, and have a circular opening 6 feet diameter in the centre of each, from which rectangular wrought-iron trunks, e e, are carried down for the entrance of the air; the bearings for the fan shaft n being fixed in the outer sides of these trunks, which are strengthened for the purpose by vertical cast-iron standards r bolted to them, and resting upon the bottom foundation stone o.

The two air trunks e e join together below the fan, as shown in *fig. 676*, and communicate with the pit p by means of a horizontal tunnel, i, which enters the pit at 21 feet depth from the top.

The fan is driven by a small direct-acting non-condensing engine, k, which is fixed upon the face of one of the vertical castiron standards r, and is connected to a crank on the end of the fan shaft n. The steam cylinder is 12 inches diameter and 12 inches stroke, and is worked by steam from the boilers of the winding engine of the pit, at a pressure of about 13 lbs. per square inch. The eccentric l for the slide valve is placed just inside the air trunk e, and works the valve through a short weighth shaft, m, with a lever on the outside.

The pit p, *fig. 676*, is of an oval form, 10 feet by 18 feet, and divided near the centre by a timber brattice, n, the one side forming the upcast shaft and the other the downcast. Both of these are used for winding, and the cages o, in which the trucks, &c., are brought up, work between guides fixed to the timbering of the pit. The pumps r are placed in the downcast shaft.

In order to allow of the upcast shaft being used for winding, the top is closed by an air valve, x, which is formed by simply boarding up the under side of the ordinary guard upon the mouth of the shaft, leaving only the hole in the centre through which the chain works.

This air valve x is carried up by the cage o, on arriving at the top of the shaft, as in *fig. 676*, and then drops down again flat upon the opening, when the cage is again lowered.

During the time that the valve is lifted, its place is occupied by the close bottom of the cage o, which nearly fills the rectangular opening left at the top of the shaft. By this simple means it is found practically that a complete provision is made for keeping the top of the upcast shaft closed, and maintaining a uniform current of air up the shaft; for the leakage of air downwards through the top whilst the cage is in the act of opening or closing the air valve, and through the small area that always remains open, is found to be quite immaterial, and the surplus ventilating power of the fan is amply sufficient to provide against it.
WASHING COAL. 1069

In the original construction a more perfect air valve was supposed to be requisite, and was provided by the inclined flaps s s, which are fixed just above the horizontal tunnel t. These are fitted closely together, leaving only a small opening in the centre for the chalm to pass through, and were intended to be opened by the ascending cage coming in contact with them, closing again directly by means of balance weights before the air valve n at the top of the shaft was opened, so as to preserve a thorough closing of the top of the shaft. The flaps were to be opened again by a lever from the top to allow the cage to descend. However, it was found on trial that the valve n at the top was amply sufficient; and consequently, although the other valves were also provided, they have never been put into use.

The total depth of the pit is nearly 300 yards, and at a depth of 120 yards a split of air is taken off, and coured through workings from which coal and fire-clay are got; the larger portion of the air descends to the bottom of the pit, and is there split into many courses, to work two separate seams of coal and a vein of iron stone. The total length of road laid with plates or rails in the workings is about 7 miles, and the working faces amount to nearly double that distance. The longest distance that is traversed by any single course or split of air, in passing from the downcast to the upcast shaft, is nearly 2 miles. The quantity of materials raised from the pit is about 500 tons daily.

The following Table gives the results of a series of experiments made with this ventilating fan by Mr. R. S. Roper, showing that the quantity of air delivered at the velocities of 60 and 80 revolutions of the fan per minute is 45,000 and 56,000 cubic feet per minute, with a velocity of current of 782 and 1,027 lineal feet per minute respectively, or about 9 and 12 miles per hour; and the degree of vacuum or exhaustion in the upcast shaft is 5 and 9 inches of water respectively.

### Synopsis of Experiments on Fan Ventilation.

<table>
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<tr>
<th>Height of Boreometer</th>
<th>Temperature by Fahrenheit's Thermometer,</th>
<th>Amount of Air in Fan per minute</th>
<th>Water gauge, in.</th>
<th>Cubic feet of Air per minute</th>
<th>Theoretical Consumption of Coal per foot</th>
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<td>Mean of twelve experiments, Natural Ventilation</td>
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<td>100</td>
<td>64.10</td>
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<td>Mean of four experiments, Fan Ventilation</td>
<td>92.35</td>
<td>98.85</td>
<td>55.10</td>
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<td></td>
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<td>Mean of five experiments, Fan Ventilation</td>
<td>92.35</td>
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The speed at which the ventilating fan is usually worked is about 60 revolutions per minute, giving a velocity at the circumference of the fan of 2,548 feet per minute; 45,000 cubic feet of air per minute are then drawn through the mine, nearly one-third of which ventilates the upper workings, and the rest passes through the lower workings.

In these experiments the mode adopted for ascertaining the velocity of the air currents was by calculation from the difference of pressure, as observed by means of a carefully constructed vacuum gauge, the results being checked by the anemometer and by the time of passage of the smoke of powder fired at fixed distances by means of wires from a volatile battery at the top of the shaft.

For further information upon this subject see articles, MINES; VENTILATION OF; PIT COAL; and VENTILATION, vol. ii.

VERJUICE. (Varjes, Fr.; Aperg, Germ.) A harsh kind of vinegar, containing much malleic acid, made from the expressed juice of the wild crab apple.

VINE BLACK. A black procured by charring the tendrils of the vine and leavelling them.

W WASHING COAL. M. Berard is the inventor of a very successful apparatus for purifying small coal. He exhibited his arrangement at the Great Exhibition of 1851, receiving the council medal. The decoration of the Legion of Honor and a gold medal was also awarded to him at the Paris Exhibition in 1855. This apparatus, to be presently described, effects, without any manual labor, the following operations:

1. The sorting of the coal by throwing out the larger pieces.
2. Breaking the coal, which is in pieces too large to be subjected to the operation of washing.
3. Continuous and perfect purification of the coal.
4. Loading the purified coal into wagons.
5. Loading the refuse (pyrites or schist) into wagons for removal.
WASHING COAL.

The power required for the apparatus is that of from four to five horses, and the machine can operate upon from 80 to 100 tons of coal in about twelve hours, if fitted up near the colliery. The expense of the operation of purifying is stated to consist solely in the wages of the workmen charged to conduct the labor of the machine.

The following description of the figs. 679 and 680, will render the arrangements of M. Berard's machine readily intelligible.

The coal is carried from the mine on a staging, for example, and the tram-wagon n is unloaded into a hopper, c, either by opening the bottom or by tilting it (as in the position represented by the dotted lines a) by means of a lever. It falls afterward either on to a table or a movable grating, n, formed of frames, or of a series of stages, of sloping perforated plates, which immediately sorts it into as many sizes as there are perforated plates.

This grating is suspended out of a perpendicular by four chains or iron rods, c, e, fixed to the framework of the staging. It is moved by means of a cam motion (an arrangement of a cam and tongue montonnet) c', and falls back by its own weight against the stops, which produce convolutions or vibrations favorable to the clearing out of the holes and to the descent of the materials. The motion communicated to the grating admits of a much less inclination being given to it than would be the ease if it were fixed; the sorting is effected quicker and more perfectly, besides which the differences of level which it is necessary to preserve are maintained.

The larger pieces rejected by the first plate reach the picking table, where a laborer picks out the largest stones and extraneous substances as fragments of castings, iron, &c.

The fragments which have passed through the upper plate, and are retained by that below, descend direct to the crushers f, f', situated below. Lastly, the fine portions of the coal which have passed through the second perforated plate fall on to a solid bottom, α, whence they are thrown, delivered direct into the pit by means of a fixed shoot, c.

The crushing cylinders f, f' are made with a covering of cast-iron, mounted on an iron shaft. This covering can be easily replaced when worn out. It has on its surface small grooves, which are usually placed longitudinally, parallel with the axis of the cylinder, in order to avoid the slipping of the substances operated on. But it is also necessary to crush fragments of slate which gain admission with the coal, and these consisting of thin, flattened laminae, it would be necessary to bring the crusher closer than would be required to reduce the coal which is of a more cubical form to the proper size.

In order to obviate this difficulty another series of grooves are formed on the surfaces of the crusher transversely to those already described, the intersection of the two producing
projections in the form of quadrangular pyramids, with slightly rounded tops. In coming
between the projections of the crushers the fragments of slate, being unable to pass, are
broken up without reducing the coal to a smaller size than is required.

When the coal has undergone a preliminary sifting, which has removed all the pieces
exceeding 6 or 7 centimetres in size, one pair of crushers is sufficient. In that case the
grating may be dispensed with altogether by discharging the coal direct into the pit, and
returning from the sifter to the washer the pieces of coal which have not been able to pass
beyond the first perforated plate.

The small coal resulting from the washer, or from the sifter, by means of the jigger, is
delivered into a common pit placed under the washers. The pit is shaped like an inverted
quadrangular pyramid, the three faces of which are inclined to one another at an angle of
45°, to facilitate the descent of the substance, and the fourth is usually vertical. It is on
the latter that an opening is made, which is regulated by a flood-gate.

An elevator, formed of an endless chain, with buckets, raises the coal from the bottom
of the pit, places itself sufficiently high to allow of the final discharge, which may take place
into the wagon.

The rate of ascent of the buckets and their capacities are calculated so as to raise 160
to 200 tons of coal in the working hour; but this quantity may be diminished by means of
the flood-gate in the pit.

The coal discharged by the elevator falls on the sorter, which ought immediately to di-
vide it, according to size, and distribute it to the ferry-boats.

The classifier is formed of a kind of oblong rectangular chest, made of iron plates, in
the inside of which are placed stages of perforated plates, the apertures in which decrease
in a downward direction. Sufficient space is allowed between each plate for the motion of
the materials. At the bottom of the perforated plates are disposed inclined planes for
throwing on one side the product of the sifting, which escapes through a slope made on the
side of the sifter. A bottom fixed to the classifier itself, and like it movable, receives the
dust in the finest numbers, if the sifting has been effected in the dry way, or else this bot-
tom is immovable and fixed to longeron which support the classifier, if the sifting takes
place in water, as we are about to point out.

The classifier is suspended by two or three pairs of articulated handles turning on axles
fixed to longeron: by that means it enjoys an extreme freedom of motion in a longitudinal
direction. A rapid reciprocating motion is communicated by a "bielle," which receives the
action of a bent axle firmly established on a foundation fixed on the principal wall of the
chamber of the machine. The motion of rotation is communicated to the axle by the dis-
position of an iron pinion d'angle working into a.

The box is formed of a rectangular chest in cast-iron, l', one part of the bottom of which
is inclined at 45°, the other lower parts remaining horizontal.

Opposite one of the lesser sides of the rectangle is placed a cylinder, o, opening into the
oblong chest at about half its height. The chest l' is prolonged under the cylinder, in or-
der to increase the stability of the system and the capacity of the drain-well, (planard.)

A cast-iron box, m', is firmly fixed in the interior of the box, on flanges of cast-iron
with vertical faces. This box has a slight inclination from m' toward m''. It is covered with
a perforated plate, usually of copper, fastened to the frame by a number of iron pins or
bolts easy of replacement. The size of the holes varies according to that of the matters
brought into the box.

A cast-iron door, n, traverses, opening outward, is fixed at a slight height above the
frame, serving as a kind of partition dividing the materials in the box, and against it a flood-
gate, n', by means of which the opening beneath the cast-iron door may be closed at pleasure.

A counter flood-gate, n'', is placed at the lower extremity of the frame; in raising it a
barrier is formed of variable height, by means of which the substances between the flood-
gate and counter flood-gate may be arrested.

A piston, c, receives from the machine a sufficiently rapid reciprocating motion.

Every thing being thus arranged, if the box is supposed to be filled with water to the
level of the front face at n', and that the substances to be washed fill the space in the box
between this level and the perforated plate of the frame, the piston working upward and
downward will press the water in the body of the cylinder, and will force it by its incom-
pressibility to pass through the holes in the perforated plate; it will establish above this
plate an ascending current, which, if of sufficient power, will raise the substances submerged.

The resistance to the rise of each body will be in proportion to its specific gravity, and
the height it will be carried will follow an inverse law, supposing the fragments to be of
nearly equal size.

The slates which fall over the counter flood-gate fall into a pocket, a reservoir, x, whence
they are discharged on opening a flood-gate, x'. Pressed by the upper column of water,
they slide with a slight admixture of water on the inclined plane x' x'', which can be pierced
with holes; the water escapes, and the slate only falls directly into the wagon of dis-
charge.
WASHING COAL.

The bent axle of transmission, s s, moves in a groove turning on a pivot at its extremity. The rotation of the axle communicates an oscillating motion to it.

The deposit formed in the drain-well is emptied through an opening of the flood-gate placed at the lower part. An opening serving as a man-hole is reserved for effecting internal repairs without the necessity of raising the frame.

All coal contains a portion of earthy matters or impurities which, in the form of bands or scales, are generally in some degree apparent to the eye, and constitute the ashes and clinker left by combustion. The small coal which is sent out of mines necessarily contains a still larger proportion, frequently exceeding 10 per cent., consisting chiefly of shale and iron pyrites derived from the roof or floor of the seam of coal, or from the hands of impurities interstratified with it. Generally these impurities are so incorporated with the mass of the coal that it must be crushed in order sufficiently to detach them. The pyrites, which contains nearly the whole of the sulphur found in coal seams, is well known to be very injurious either in a heating or smelting furnace, in the manufacture or working of iron, in gas-making, in coking, and other processes.

Many seams of coal already sunk to, or portions of seams in work, are left under ground as unsalable in consequence of the impurities they contain. Small coal sells at a low price, chiefly in consequence of its impurities and the defective coking property which they occasion. It has been estimated that an amount not far short of the quantity of coal sold is sacrificed in producing a commercial article of adequate quality and description. The enormous consumption of coal in this country, amounting to 70 millions of tons per annum, renders the utilization of a larger portion of the more valuable seams now in course of being exhausted, and the bringing into the market of other seams, objects of national importance.

The differences between the specific gravities of coal and its impurities, allow of their being separated by the action of water when sufficiently crushed. The water process hitherto most commonly adopted is that known as "jigging," which consists in forcing the water alternately up and down through the mass of coal. The downward current of water in "jigging" is prejudicial, and entails a large sacrifice of the finer particles of the best coal; whilst the upward current, from its rapidity and irregularity, is costly both in time and power, besides failing to effect the more perfect separation which is obtained by a slow, continuously ascending or pulsating current, regulated to the proportion of shale in the coal, and to the size of the particles to be acted upon.

Mackworth's patent coal purifier.—In the late Mr. Herbert Mackworth's purifier, fig. 681, the water ascends with a velocity of an inch or two in a second. It is sufficient to keep the particles in constant agitation, and the area of the separator can be reduced to a small fraction of its former size. The coal is supplied into the machine in a uniform stream, and as it is purified is raised out of the water on to a perforated plate, and delivered
by the coal-sweep into a long perforated shoot, down which it descends into the tram or wagon placed to receive it. The purified coal is thus obtained for coaling and other purposes in a comparatively drier state. The shale, which has during the separation accumulated in the shale-box, will discharge itself into another tram without stopping the machine, if the shale valves are first closed by the valve lever before throwing open the shale door.

The pump, or agitator, is capable of throwing from 50 to 200 gallons of water per minute, according to the size of the machine. The endless band rises or lowers the coal from the hopper into which the coal trams are tipped.

The advantages of the machine may be thus summed up:—

1st. The more perfect separation of the impurities. If the coal is not sufficiently crushed, even the fragments of coal containing shale or pyrites can be separated as well as the shale, by regulating the velocity of the water. By increasing the speed of the machine and the velocity of the water, the separation of the impurities may be limited to any extent desired.

2d. The saving of coal. This may be estimated at from 6d. to 1s. 6d. per ton. The ordinary washing processes sacrifice more than 20 per cent. in weight, of which more than one-half is the best coal. In this machine the water does not pass out, but is used over and over again in a continuously circulating stream. The loss of coal does not exceed 2 per cent., and is generally under 1 per cent.

3d. The economy in the power required to work the machine. 1-horse power will suffice to work a machine with pump and elevator capable of purifying 50 tons of coal per day.

4th. The saving in manual labor.

5th. The quantity of water required is comparatively insignificant. A small supply of water is required to replace that absorbed by the wetting of the shale and coal.

6th. The coal is delivered drier than by any other existing process.

7th. The largest machine stands in an area of 9 feet square, and motion can be given off any existing engine by a strap to a pulley making 40 revolutions per minute, at a height of about 12 feet above the ground. The height given to the machine is for the purpose of passing trams underneath it to receive the purified coal and shale as they are delivered.

The machine requires no foundation, and is easily removable.

8th. The great economy of the process in every point of view is important to—

The coke trade.—Many coals when deprived of their impurities will coke which never coked before, and the quality of every description of coke may be greatly improved. In coals above the average in quality, it has been found that the cinder may be made into water purification by reducing by four-fifths in quantity. The two principal sources of cinder—the whitish scales of carbonate of lime and the iron pyrites—are removed. A coke more uniform in texture and better in appearance is produced, and different descriptions of coal may be simultaneously mixed and purified by this machine. A cost of 3d. per ton on the coke will remove those impurities for which the consumer now pays at the same rate as the coke itself. An increase in the make and quality of the iron results from using purified coke in blast furnaces.

Persons using steam.—The amount of ash and cinder from a coal, by no means represents the full amount of loss and waste occasioned by them. The coal is imperfectly burnt, and the fire bars are injured. By removing the impurities, much of the labor in attending boiler fires may be spared, and the steam kept up more regularly. In steamers, and whenever the freight of coal is heavy, these advantages are peculiarly important.

Gas companies.—Gas may be produced comparatively free from sulphur, as well as a purer and more valuable coke. By a small addition to the cost of the machine the coal may be delivered in a dry state.

Smiths and workers in metal.—A coal purer than the large coal is produced. Better work and metal and cleaner hearths are the results. Smiths are paying in several instances nearly double the former prices for coals which have been purified. In puddling and other furnaces the advantages of pure coal have been well ascertained.

Patent fuel companies.—In all cases where freights are heavy and the manipulation of the fuel costly, purity in the raw material is essential.

Colliery owners.—Coal and shale in lieu of being thrown into the gob can be brought out of the mine and separated for from 1s. to 2s. per ton, including hauget, &c. Crop coal, old pillars, and creeps may be turned to account.

The spontaneous combustion in the wastes of some mines may be prevented by bringing out the whole of the small coal and pyrites at a now remunerative price. New coal seams may be brought into the market, to the benefit both of the producer and consumer.

In working this machine the coal tram is tipped into the coal hopper; it is then conveyed by the elevator in a continuous stream into the machine, and the purified coal is delivered continuously from it. The shale and pyrites are delivered in a continuous manner by the dregler, or Jacob's ladder. The workman has only to attend to the placing of these wagons and regulating the amount of opening of the valves, which allow the shale to descend into the shale box after it is separated.
WATER PRESSURE MACHINERY FOR MINES.

The revolving hopper allows the coal to descend gradually into the separator, where a slow current of water is driven upwards through the mass of shale and coal, at a velocity of from 4 to 5 feet per minute, by the agitator or screw. This water passes back again by the finely perforated plate, and with the fine silt suspended in it, is again driven upwards by the screw to undergo a repetition of the process. The gentle agitation produced by this current separates the shale and pyrites from the coal in the separator, the two latter descend through the valves and are taken up by the dregder, whilst the former is pushed upwards out of the water by the curved arm; and as soon as the water has drained off, the coal falls on to the shoot, which conducts it to the tram. A brush following the arm helps to keep the holes in the perforated plate open. The valves remain constantly more or less open, according to the indications given by the dregder, and are regulated by the valve lever. The water required to replace that absorbed by the dry coal and shale enters by the hopper and flows slightly inwards through the shale valves as the shale is coming out.

The objects said to be attained by the machine are: 1st, a more perfect separation of the impurities than by the jigging or budding processes; 2d, a saving of from 5 to 15 per cent. of coal; 3d, economy of power and manual labor; 4th, saving of water and the delivery of the coal in a drier state.

Machines have been established in Scotland, Cumberland, Derbyshire, Gloucestershire, and Wales, to purify from 20 to 100 tons of coal per day, at a cost not exceeding 3d, per ton, and with a loss not exceeding 2 per cent. of coal.

WATER PRESSURE MACHINERY FOR MINES. Considerable attention has been given to the construction of pressure engines by Mr. Darlington, who has actively engaged some years since in effecting the drainage of the Alport Mines, in Derbyshire. See fig. 682.

The first engine erected by him had a cylinder 50 inches diameter, and a stroke of 10 feet; the piston-rod passed through the bottom of the cylinder and formed a continuation with the pump-rod, whilst the valve and catenat gearing was worked by a rod connected with the top of the piston, which gave motion to a beam and plug-rod gearing. The column of water was 122 feet high, affording a pressure on the piston of about 38 pounds per square inch, or more than 50 tons on its area. The water was raised from a depth of 22 fathoms, by means of a plunger 42 inches diameter, and in very wet seasons it discharged into the shaft nearly 5,000 gallons of water per minute. Water was admitted only on the under side of the piston, and in order to avoid violent concussion in working; two sets of valves were employed, the larger being cylindrically shaped, 22 inches diameter; and the smaller 5 inches diameter. In making the upside of the engine the cylindrical valves admitted a full flow of water for about 2/3 of the stroke, and then commenced closing, but at this stage the small valve opened, through which passed sufficient water to terminate the stroke. In this way the flow of water in the column was gradually slackened, and finally brought to a state of rest without impinging impact to the machinery. The speed of the engine was regulated by sluice valves, one fixed between the engine and the pressure column, and the other upon the discharge-pipe.

The cylindrical valves were made of brass with a thin feather-edged beat, and kept tight by a concentric boss, projecting from the nozzle, upon which hemp packing was laid. This was pressed down by a projection in the under surface of the valve boss. The water thus acted on the exterior of the valves between the zone of packing and the seatings, and when opened passed through the latter. Besides this engine, others of a different construction were designed and erected by Mr. Darlington, but the one to which he gave preference for simplicity, cheapness, and smoothness of action, is illustrated in the following woodcut.

This engine has one main cylinder, a, resting on strong cast-iron bearings, b, fixed across the shaft. The piston-rod c is a continuation of the pump-rod s, and works through the cylinder bottom n. In front of the cylinder a, is a smaller one, k, with differential diameters for the admission and emission of water, and right and left are sluice valves not shown for regulating the speed of the engine. Connected with the second cylinder is a small 3-inch auxiliary cylinder, r, provided with inlet and outlet regulating cocks.

In starting this engine the sluice valves and regulating cocks are opened, the water then flow from the pressure column o, into the main cylinder a, through the nozzle cylinder, r, and acts under the piston k, until the upstroke is completed. The piston r has a counter piston, k, of larger diameter, and when relieved from pressure on its upper surface, the water acting between them forces it upwards, in which case the pressure is cut off from the main piston, and the water contained in the cylinder a is free to escape under the piston, through the holes l. With the emission of water from the main cylinder through k, the downstroke is effected. The downward displacement of the pistons, r, and k, is performed by the auxiliary cylinder f, and pistons, n, o; the pressure column is continually acting between these pistons, and by their alternate displacement by the fall-bob r, and canti-abor q. The water is either admitted or prevented from operating on the upper surface of the piston k. The water from the top of piston k escapes through the aperture n. The motion of the canti-abor q, is effected by tappets fixed on the pump-rod s.

One of these engines was recently in operation at the Minera Mines, in North Wales.
The cylinder was 35 inches diameter; stroke 10 feet, pressure-column 227 feet high. Its average speed was 80 feet and maximum speed 140 feet per minute. The pressure of
water under the piston was 98 pounds per square inch, giving a total weight on its area of about 40 tons. This machine required no personal attendance, the motion being certain and continuous, as long as the working parts remained in order; consequently the cost of maintaining it was of the most trifling character.

In 1803, Trevithick erected an engine at the Alport Mines which worked continuously for a period of forty-seven years, or until 1850, when the mines ceased working. The water from the pressure-column acted on alternate sides of the main piston, by means of two piston valves, displaced by a heavy tumbling beam, and tilted by a projection from the pump-rod. The construction and action of this machine will be best understood by the accompanying illustration, fig. 683.

\[ A, \text{main cylinder} ; \quad B \text{and } C, \text{valve pistons} ; \quad D, \text{chain wheel, upon the axis of which is fixed a lever not shown, in connection with a tumbling beam} ; \quad E, \text{aperture through which water enters from pressure-column} ; \quad F, \text{pipe in communication with main cylinder } A, \text{and } G, \text{pipe for discharging the water admitted both above and under the main piston } n. \text{ The position of the valve pistons in the woodcut shows that the pressure-column is supposed to be flowing through the holes } i, \text{ upon the piston } n, \text{ producing a down stroke, and that the water which has been introduced under this piston in order to make the up-stroke is leaving through the pipe } j, \text{ holes } k, \text{ and outlet pipe } o. \]

By referring to Hydraulic Cranes, the principles adopted by Sir Wm. Armstrong will be understood.

It is not necessary to repeat that part of the subject in this place, but it remains to notice the applications made of the pressure derived from natural falls.

When the moving power consists of a natural column of water, the pressure rarely exceeds 250 or 300 feet; and in such cases he has employed to produce rotary motion, in preference to the original scheme of a rotary engine, a pair of cylinders and pistons, with slide valves resembling in some degree those of a high-pressure engine, but having relief valves to prevent shock at the return of the stroke, as shown in fig. 330, already described. Where the engine is single-acting, with plungers instead of pistons, as in the water-pressure engines already described, the relief valves are greatly simplified, and in fact are reduced to a single cock in connection with each cylinder, opening against the pressure, closest of the hydraulic crane. The water-pressure engines erected at Mr. Beaumont’s lead mines, at Allenheads in Northumberland, present examples of such engines applied to natural falls. They were there introduced under the advice of Mr. Sopwith, and are now used for the various purposes of crushing ore, raising materials from the mines, pumping water, giving motion to machinery for washing and separating ore, and driving a saw-mill and the machinery of a workshop. In all these cases nature, assisted by art, has provided the power. Small streams of water, which flowed down the steep slopes of the adjoining hills, have been collected into reservoirs at elevations of about 200 feet, and pipes have been laid from these to the engines.

Another application of hydraulic machinery at the same mines is now being made in situations where falls of sufficient altitude for working such engines cannot be obtained, which from its novelty deserves special notice. For the purpose of draining an extensive mining district and searching for new veins, a drift or level nearly six miles in length is now being executed. This drift runs beneath the valley of the Allen nearly in the line of that river, and upon its course three mining establishments are being formed. At each of these
WATER, SEA.

power is required for the various purposes above mentioned, and it was desired to obtain this power without resorting to steam engines. The river Allen was the only resource, but its descent was not sufficiently rapid to permit of its being advantageously applied to water-pressure engines. On the other hand, it abounded with falls suitable for overshot wheels, but these could not be applied to the purposes required without provision for conveying the power to many separate places. Under these circumstances it was determined to employ the stream through the medium of overshot wheels in forcing water into accumulators, and thus generating a power capable of being transmitted by pipes to the numerous points where its agency was required. In this arrangement intensity of pressure takes the place of magnitude of volume, and the power derived from the stream assumes a form susceptible of unlimited distribution and division, and capable of being utilized by small and compact machines.

A somewhat similar plan is also adopted at Portland Harbor, in connection with the coaling establishment there for the use of the navy. The object in that case is to provide power for working hydraulic cranes and hoisting machines, and more particularly for putting coal into war steamers. A reservoir on the adjoining height affords an available head of upwards of 300 feet; but in order to diminish the size of the pipes, cylinders, and valves connected with the hydraulic machinery, and also with a view of obtaining greater rapidity of action, a hydraulic pumping engine and accumulator are interposed, for the purpose of intensifying the pressure and diminishing the volume of water acting as the medium of transmission.

WATER, SEA.—rendered fresh. (Communicated by Dr. Normandy.) The analyses of sea water which have been made at various times, and the results of which will be found elsewhere, prove that that liquid contains from 3½ to 4 per cent. of saline substances, two-thirds at least of which are common salt, and also a certain quantity of organic matters, all of which substances impart to it its well-known taste and odor, and render it unfit for drinking or other domestic purposes.

To render sea water drinkable, and thus avoid the accidents resulting from an insufficient supply, or from an absolute want of fresh water, in sea voyages, is a problem which may be said to have engaged the attention of men from the very moment they ventured to lose sight of the friendly shore and become navigators; gradually, as the enlargement of commercial operations extended the length of sea voyages, the difficulty of preserving in a pure state the fresh water taken in store, the necessity of putting up at stations for procuring a fresh supply of it when it is exhausted, the great gain to be realized by being enabled to devote to the stowage of cargo the valuable space occupied by water-tanks and water-casks, have induced many people at various times, and for many years past, to contrive apparatus by means of which sea water would be rendered fit to drink, or by means of which good fresh water could be obtained therefrom.

Fresh water can be obtained from sea water in two ways; the one by distillation, the other by passing it through a layer or column of sand, or of earth, of sufficient thickness or length. In effect, if sea water be poured at A, in a pipe 15 feet high, and full of clean dry sand, the water, which will at first flow at n, will be found pretty fresh and drinkable, but as the operation is continued, the water which flows at n soon becomes brackish; the brackishness gradually augmenting, until, in a very short time, the water which flows at n is actually more salted than that poured at A; because the latter dissolves the salt which had been first retained by the sand, which must then be removed, or washed with fresh water, a process evidently useless for the purpose in question. This phenomenon, according to Berzelius, is due to the interstices between the grains of sand acting as capillary tubes; and as, at the beginning of the operation, the effect depends more on the attraction than on the pressure of the liquid poured in one of the branches of the tube, the salt is partly separated from the water which hold it in solution, the latter lodging itself into the interstices of the sand, and filling them; if, when the mass of the sand is completely wetted, a greater quantity of sea water is poured upon it, the weight of the said sea water first displaces and expels the fresh water; but as soon as the interstices of the sand have thus been forcibly filled up with sea water, the water flowing at n becomes more and more salted; wherefore this filtration cannot yield more fresh water than can be contained in the interstices of a column of sand of a certain length and proportionate to the saltness of the sea water.

Howbeit, the removal of the salt from sea water, so as to obtain fresh water therefrom, is, practically speaking, an impossibility, except by evaporation. At first sight one would think that it is sufficient to submit sea water to distillation to
convert it into fresh water, and that the solution of the problem is altogether dependent upon a still constructed so as to produce, by evaporation, a great quantity of distilled water, with a consumption of fuel sufficiently small to become practicable.

Distillation at a cheap rate is doubtless an important item, and fuel being a cumbersome and expensive article on board ship, it is superabundantly evident that, supposing all the apparatus which have hitherto been contrived for the purpose to answer equally well, that one would clearly merit the preference which would produce most at least cost; but there are, besides, other desiderata of a no less primary importance, and it is from having neglected, ignored, or being unable to realize them, that all the apparatus for obtaining fresh water from sea water, which have been from time to time brought before the public, have hitherto, without exception, proved total failures, or, after trial, have been quite discarded, or fulfil the object in view in a way so imperfect or precarious, that, practically speaking, the manufacture of fresh water at sea, or from sea water, may be said to have been, until quite lately, an unaccomplished feat. In order to understand the nature of the difficulties which stood in the way of success, a few words of explanation become necessary.

When ordinary water, whether fresh or salt, is submitted to distillation, the condensed steam, instead of being, as might be supposed, pure, tasteless, and odorless, yields on the contrary a liquid free from salt, it is true, but of an intolerably nauseous and empyreumatic taste and odor, which it retains for many weeks; it is, moreover, insipid, flat, and vapid, owing to its want of oxygen and carbonic acid, which water in its natural state possesses, and of which it has been deprived by the process of distillation. In the absence of ordinary fresh water, this distilled water, however disagreeable and objectionable it may be, is of course of use so far as it is fresh, but as long as they can obtain a supply from natural sources, even though this may be of so bad a quality as to endanger their health or their lives, as evidenced by the report of The Times' Own Correspondent in reference to the water supplied to the crews of our ships in the Baltic during the Crimean war.

With a view to remedy the defects just alluded to, various means have from time to time been proposed and employed; such as the addition of alum, sulphuric and other acids, chloride of lime, &c.; but it is evident that chemical reagents cannot effect the object; but if even they did, their use is always unsafe, for their continuous and daily absorption might, and doubtless would, cause accidents of a more or less serious nature, not to speak of the trouble and care required in making such additions. Liebig said with both authority and reason, that, as a general rule, the use of chemicals should never be recommended for culinary (or food) purposes, for chemicals are seldom met with in commerce in a state of purity, and are frequently contaminated by poisonous substances. On the other hand, the percolation through perforated barrels or coarse sieves, porous substances, plaster, chalk, sand, &c., the pumps, ventilators, bellows, agitators, which have been proposed to mix the distilled water obtained, and render it palatable, are slow in their action, of a difficult, inconvenient, or impossible application; and as to leaving the distilled water to become aerated by the agitation imparted to it in tanks or casks by the motion of the ship, this must be continued for a length of time, proportioned of course to the vigor of the oscillations imparted to the ship by the violence of the waves, and the time thus required is always considerable; yet in this way, and finally by pouring the water several times from one glass to another before drinking it, it may become fully aerated, but without entirely losing its vapid and nauseous taste and odor, and in fact the report of the correspondent of The Times', above alluded to, shows that this method is attended with but indifferent success. I shall presently explain why no system or method of aeration whatever could be attended with success, in the production of perfect fresh water from salt water, notwithstanding the great ingenuity displayed in their endeavors to realize the object in view by persons who, some of them at least, though of consummate skill as engineers or philosophers, or as men of general knowledge, were not, it would appear, sufficiently well acquainted with the exact nature of the difficulties which stood in the way, or were not fitted for the investigation and conquest thereof. In reality the failures in this respect have been due to the fact that the aeration of the distilled water, instead of being, as everybody thought, the whole problem, is only a part of it; and we shall see, moreover, that the said aeration, to be effective, must be practised under certain conditions, in a certain manner, and is only a preparatory step, though an all-important one, to the final production of perfect fresh water.

But before proceeding further, it may not be amiss to say a few words respecting another condition in the construction of marine condensing machines, which, from not being sufficiently taken into account, frequently puts them suddenly out of service, or necessitates constant repairs. I am alluding to those condensers the joints of which are made by soldering or brazing; for the different rates of expansion and contraction of metals by heat and by cold, during the intervals of work and of rest of the apparatus, would be sure eventually to cause the soldered parts to crack and give way, an effect which the motion of the ship would of course greatly promote. This in fact was the cause of the accident which about thirty-five years ago put the lives of Captain Freycinet and of his crew in fearful jeopardy. On
WATER, SEA.

The other hand, the electro-chemical action which sets up between the metals of the solder and that of the condenser, corrodes the latter, and in either case a leak being started, the sea water penetrates through it into the apparatus, which may thus be at once put out of service after a few months' working, its unsoundness thus creating the most distressing sufferings, and putting the lives of all on board in imminent peril. It may therefore be most truly asserted that any fresh-water distilling apparatus, for marine purposes, in any part of which solder is employed, is ipso facto defective, and ought not to be trusted, the soldered parts being sure to give way from the causes just alluded to. Lastly, another condition often lost sight of (although of extreme importance,) in the endeavors which have been made to accomplish the object in question, is to obviate or prevent the deposit of saline matter which takes place when the limit of saturation has been attained, and which in a short time interferes, temporarily at least, and often permanently, with the working of the apparatus, renders frequent repairs necessary, and in all cases eventually destroys it.

The question which had been hitherto left unanswered, and yet which must be integrally solved before success could be hoped for, is the following:—

To obtain, with a small proportion of fuel, large quantities of fresh, inodorous, salubrious aerated water, without the help of chemical reagents, by means of a self-acting and compact apparatus, capable of being worked at all hours, under all latitudes, in all weathers and conditions compatible with the existence of the ship itself, and incapable of becoming incrusted, or of otherwise going out of order.

How this complex and difficult problem has been solved I will now proceed to explain:—

It is a known property of steam that it becomes condensed into water again, whenever it comes in contact with water at a temperature lower than itself, no matter how high the temperature of that condensing water may be.

It is known that the sea and other natural waters are saturated with air containing a larger proportion of oxygen and of carbonic acid than the air we breathe. In effect, 100 volumes of the air held in solution in water contain from 32 to 35 volumes of oxygen, whereas 100 volumes of ordinary atmospheric air contain only 24 volumes of oxygen. Again, ordinary atmospheric air contains only 1/1000 of carbonic acid, whereas the air held in solution in water contains from 40 to 42 per cent. of carbonic acid. The experiments which I undertook in 1849–50, with a view to determine the amount of these gases present in water, showed me that this amount varied with the state of purity of the water, that, whilst ordinary rain water contains, on an average, 13 cubic inches of oxygenized air per gallon, constituted as follows:—

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Sea water, owing to the various substances which it holds in solution, contains only on an average 5 cubic inches of gases, more than one half of which is carbonic acid; or, in other words, 1 gallon of sea water contains about two thirds less gases than ordinary rain water, and one half less gases than river water.

I have also ascertained that air begins to be expelled from such natural waters when the temperature reaches about 130° Fahr.; and we know that when the temperature reaches 212° Fahr., all the air which it contained has been expelled, and it is for this reason that distilled water contains no air.

At that time I shared the prevalent opinions of all who had interested themselves on the subject, namely, that the flat, disagreeable, and mawkish taste and odor of distilled water were due to its having been deprived of air; and knowing that the various methods adopted or resorted to for aerating distilled water by forcing atmospheric air into it had failed, and that the distilled water thus aerated spontaneously or by mechanical means, retained the abominable taste and odor just alluded to, and remained for a long time almost undrinkable, I thought that the defect was possibly owing to the air mixed with it not being of a suitable quality, the experiments which I have related having indeed shown that the composition of air contained naturally in water differed essentially from atmospheric air; and that consequently if I could reintroduce into the distilled water the carbonic acid and oxygen of which distillation had deprived it, it would then become as sweet as good ordinary water. With this view I contrived the apparatus which forms the subject of the present article.

The apparatus is represented in Figs. 685, 686. It consists of three principal parts, an evaporator, 14, a condenser, 6, and a refrigerator, 3, joined so as to form one compact and solid mass, screwed and bolted, without soldering or brazing of any kind. The evaporator is a cylinder, partly filled with sea water, into which a sheaf of pipes are immersed, so that on admitting steam at a certain pressure into these pipes it is condensed into fresh, though non-aerated water by the sea water by which the pipes are surrounded, that sea water being thus heated and a portion of it evaporated at the same time; for it is one of the properties of steam to be condensed by water, no matter how high the temperature of that water may
be, if it be only inferior to that of the steam. This non-aerated water becomes aerated, as
I shall explain presently. On board steamers, the steam is obtained directly from the boilers
of the ship; in sailing vessels it is procured from a small boiler which may, or may not
be connected with the hearth, galley, or galley.

The steam at a pressure being, of course, hotter than ordinary boiling water, serves to
convert a portion of the water contained in the evaporator into ordinary or no-pressure
steam, which, as it reaches the pipes in the condenser 6, is resolved therein into fresh aerated
water. The manner in which it becomes aerated will be explained presently. By the
process of evaporating water under slight pressure, one fire performs double duty, and thus
the first condition, that of economy, is completely fulfilled; for while, in the usual way, 1 lb. of
cold evaporates at most 6 or 7 lbs. of water, the same quantity of coals, burnt under the
same boiler, but in connection with my apparatus, is thus made to evaporate 12 or 14 lbs.
of water; or, in other words, from the same amount of coals or of steam employed, the ma-
chine which I am describing will produce double the quantity of fresh water that can be
obtained by simple or ordinary distillation; that is to say, double the quantity obtained by
the ordinary condensers.

The comparative trials made in 1859 on board H. M. ships the Sphynx, Erebus, and
Odin, at Portsmouth, before the Commissioners of the Admiralty, have most conclusively
proved the perfect accuracy of that statement.

The steam issuing from the evaporator, and which is condensed by the water in the con-
denser, imparts, of course, its heat to the sea water in it; and as this water is admitted cold
at the bottom, whilst the steam of the evaporator is admitted at the top of the condenser,
the water therein becomes hotter and hotter gradually as it ascends, and when it finally
reaches the top its temperature is about 208° Fahr.

I have already stated that water begins to part with its air at a temperature of about
130° Fahr.; therefore the greater portion of the air contained in the water which flows
constantly and uninterruptedly through the condenser is thus separated, and led through a
pipe into the empty space left for steam room within the evaporator, where it mixes with
the steam.

Now, as about six gallons of sea water must be discharged for every gallon of fresh
water which is condensed, and as each gallon of sea water contains, as we said before, 5
cubic inches of air, and whereas the utmost quantity of it that fresh water can naturally
absorb is 15 cubic inches per gallon, it follows that the steam in the evaporator, before it is
finally condensed, has been in contact with twice as much air as water can take up, the
result being a production of fresh water to the maximum of aeration, that is, containing as
much air as in pure rain water.

This aeration of the water to the maximum and with the air naturally contained in the
water in its original state, though a condition of the utmost importance, as will be seen
presently, having, to my extreme surprise, failed in removing the detestable odor and taste
in question, it became necessary to try to discover whence came that flavor which no means
of aeration could destroy, except after a considerable length of time, and even then never
perfectly. With that view I took 25 gallons of distilled water, possessing the characteristic
empyreumatic odor and taste, and having evaporated them slowly at a temperature much
below the boiling point, I found, at the end of six weeks, the inside of the little platinum
dish into which the experiment had finally been carried, covered with a thin oily film of a
most disagreeable odor, and upon rinsing the little dish in 25 gallons of excellent ordinary
fresh water, the latter immediately acquired the empyreumatic odor and flavor peculiar to
distilled water, which odor and flavor are evidently due to the destructive action of the heat-
ed surface of the vessels in which the water is boiled on the organic substances which are all
always floating in the air, or those indescribable particles of dust which are seen playing
or moving about in a sunbeam, and which have been dissolved or taken up by the water
before its distillation. That water has the power of absorbing and dissolving organic matter
in this way is, of course, well known; but it may be illustrated in a very simple manner, as
follows:—If water, from whatever source, be distilled, the distillate will, of course, be fresh
water, pure fresh water, but it will have a peculiar, nauseous, and empyreumatic taste and
odor, stronger in proportion as the heat applied to evaporate it has been more elevated; it
is that smell and taste which render it undrinkable for a while. If, when it has become
sweet again by long standing, which period may be hastened by agitation in the atmos-
phere, if, I repeat it, that distilled water be then redistilled, the distillate will be found
to have acquired again the same empyreumatic taste and odor as when it was first distilled.
How is this? Because it will, by standing or agitation, have redissolved a portion of the
air in the room in which it was kept, and along with that air it will have absorbed whatever
substances were present, dissolved or suspended in it, and those substances by their contact
with that heated surfaces of the still, yield an empyreumatic product, which taints the distillate.
On board ships, the water which is stored in for the use of crews in the usual way, in the
course of about a fortnight becomes putrid and almost undrinkable, because the organic
matter which that water contains is undergoing putrefactive fermentation. But about a month
or so afterward the water gradually becomes sweeter and sweeter, until at last it becomes
drinkable again; because, eventually, all the organic matter which it contained becomes decomposed, carbonic acid and water being the result, and although the air of the ship’s hold is none of the sweetest, such water, as just said, generally remains afterward perfectly good and palatable; because, the tanks in which it is kept being covered up, it is sheltered from fresh pollutions, and because it is now saturated with pure air, and therefore cannot absorb that of the atmosphere.

When the natural waters supplied to our habitations are obtained from impure sources, as is unfortunately too often the case, the evils resulting from their use may in some degree be remedied by putting in practice the recommendation which has been sometimes made, of boiling such water previous to employing it as a beverage; unfortunately the water, being thereby deprived of air, is, like distilled water, though in a less degree, unpleasant, and full of unctuous and heavy; it is, in fact, of difficult digestion; but there is something worse than that; water which has been boiled, or which has been distilled, by reason of its containing no air, has a great tendency to absorb or to take that of the media where it is kept, so that if distilled water which contains no air be kept in a ship’s hold, or in an impure and confined place, it will absorb precisely the quantity of air which it can absorb, namely, 15 cubic inches for each gallon, and if that air be loaded with organic particles or impure emanations, it will soon become fetid and putrid. The experiments of Dr. Angus Smith have proved that if a stream of air which has already been breathed be passed through water, the latter will retain a peculiar albuminoid matter which undergoes putrefaction with extraordinary rapidity; and the water which condenses on the cold exterior surfaces of vessels in crowded rooms possesses the same character, and acquires in a short time an offensive odor; now this is to a great extent the case with the water of ordinary condensers when allowed to become spent or to be distilled, on board ship. Thus water, though distilled, if kept in tainted rooms, will soon become foul. The only condition necessary for distilled water not to become putrid or offensive is to saturate it with pure air, because in that case there is no room left for other gases to impregnate it, (at least, practically speaking, and in the ordinary conditions of domestic or of ship economy,) and to keep it in covered vessels or tanks.

Now, although aération alone is, as I have just said, powerless to destroy the nauseous odor of distilled water within a time practically useful, this aération, when effected in the manner which I have described, is of the utmost importance; since if even all the other conditions of the problem had been complied with—all, except that one, the apparatus, economical and perfect though it might have been in all other respects, would have been comparatively useless. I would strongly urge the importance of aérating the fresh water in the manner which I have described—that is to say, not with ordinary atmospheric air, but with that air which was naturally contained in the water before its distillation; because aérating it mechanically with ordinary atmospheric air, by simple ventilation or agitation, is far from answering the purpose so well, for the reasons which I have already stated. Having thus found that the cause of the odor and taste was due to the presence of empyreumatic products, it became evident that, whereas the fresh water produced by my apparatus was arrayed in the same manner and to the same extent as that obtained from the very best sources, and equal to it in every other respect, the removal of these ill-smelling and ill-tasting principles was the last obstacle to the entire success of the operation.

Now, if a tree, for example, after having been cut down, is left exposed to the action of the air on the spot on which it lies, we know that, in the course of time, its exterior becomes soft and friable, and that it gradually sublimes into dust. The tree, in that case, is said to be decaying; and, in effect, after a greater or less number of years, it will be found that all the combustible parts, that is to say, all those parts which would have been burnt off if the tree had been set fire to, have vanished, and been volatilized, nothing being left behind but the incombustible parts, that is to say, the earthly constituents of the tree. Whether the tree is destroyed by actual burning or by spontaneous decay, the result is the same; the only difference is, that in the first case the combustion is rapid, and is energetically accomplished, with disengagement of heat and of light, in a few hours; in the second case, the combustion is slow, without sensible elevation of temperature, and a period of thirty, or perhaps forty years may be required to accomplish it, and for the tree to disappear completely; it is only a question of time; whether the tree is burnt in a fire, or allowed to decay in the air, the final result is the same; the carbon and hydrogen of its wood being oxidized, or burnt by the oxygen of the air, give, the one carbonic acid, the other water, both of which disappear, and a fixed residue, namely, ashes, remains. But if, instead of leaving the tree whole, it be cut into pieces, into shavings, into fragments of shavings, into shreds—then its combustion in a fire will be completed in a few moments; or spontaneously in a few months, as indeed is the ease with farm-yard manures, which are spread on the ground, and of which nothing remains in the ensuing year—nothing but the incombustible part thereof—the earthly portion, the ashes, mixed with the soil.—There is it that a corpse which, while putrefying, evolves a revolting odor, becomes inodorous when it is put into a hole in the ground, covered with earth, wherein it continues nevertheless to decay and to rot, so entirely and effectually, that after a certain time nothing remains but
bones, or the earthy matter of those bones? What has become of the muscles, of the fat, of the nerves, tendons, tissues of all kinds? They have been burnt, oxidized, converted into carbonic acid and water; the sulphur therein has been converted into sulphuric hydrogen, and that again into sulphuric acid and water; the nitrogen has been converted into ammonia, &c. &c. Whence it is seen, that all dead organic matter is eventually burnt up by the oxygen of the air; and that this combustion, whether rapid or slow, is accelerated by the greater or less degree or state of division in which it is exposed to the action of that gas.

Now Dr. Stenhouse, several years ago, I believe, found that the power which charcoal possesses of purifying tainted air is owing to its burning in an insensible manner the substances to which the bad odor was due; and acting, therefore, upon this discovery, I conceived that in order to burn a substance spontaneously in that manner, it mattered not whether the oxygen of the medium into which the said substance was placed was a mixture of oxygen and nitrogen, (atmospheric air,) or a mixture of oxygen and water, (water aerated by my process,) since oxygen alone was the supporter of combustion, the nitrogen having nothing to do with the burning of the substance, any more than the water of the aerated water. And accordingly, on experimenting in that direction, I found that charcoal has the power of destroying the empyreuma of distilled water when such water is aerated, that is to say, when it contains free oxygen. I found by experiments, performed on a somewhat extensive scale for many months, that two cubic feet of charcoal are sufficient to remove entirely the empyreumatic odor and taste of distilled water, produced at the rate of 600 gallons per diem, and that the charcoal never wants renewing, because it does not act as a filter, but as a fire grate, the substance burnt being the empyreumatic product, and the result of the slow combustion thereof being the ordinary products of combustion, to wit, carbonic acid and water. I have every reason to believe, from the length of time during which several of my apparatuses have been in operation, both on board a large number of ships and on land, that such a filter once made will last for ever, because the charcoal disinfects the water, so to speak, as it does air, not by mechanical separation, but by actual, though insensible combustion. The water as it issues from the apparatus is perfectly sweet, tasteless, inodorous, and saturated with its proper and normal quantity of oxygenized air and carbonic acid; it is of sparkling cleanness, and being refrigerated in traversing the sheaf of pipes of the refrigerator, surrounded by cold sea water at the lower part of the apparatus, it is fit for immediate use.

These qualities I sincerely affirm are not in the slightest degree exaggerated, and a multitude of testimonials establish in an incontrovertible manner that such is truly the case.

And thus is the second condition, that of aeration, of digestibility, of wholesomeness accomplished, whereby the fresh water produced is rendered at once not only drinkable, but so sweet, limpid, and fresh, that it cannot be distinguished from the very best spring water.

During the experiments or comparative trials which took place at Portsmouth in 1859 before the Committee of the Admiralty, between my apparatus and that of the late Sir Thomas Grant, with which all H. M. steam ships were then provided, a very curious phenomenon took place, which corroborated in a startling manner the explanation which I have given of the nauseous odor of ordinary distilled water. The circumstances under which the phenomenon was produced were as follows:

On the 20th of October, 1859, steam having been got up in one of the boilers of H. M. ship "Olive," that steam was turned in precisely equal quantity to each of the apparatuses under trial, (Sir T. Grant's and mine.) The first experiment was completed about 3:30 of the ensuing morning. The fire was then "banked up" for the rest of the night; the general steamcocks supplying the steam to both apparatuses was turned off; both apparatuses of course became quite cold, and the residuary steam in the boiler was used by the engineer for working his donkey pump. Toward 12 o'clock of the ensuing day the experiments were resumed; steam again got up for the purpose, and an equal quantity of it turned as before into each apparatus.

When, however, a boiler is not at work, or has been even a few hours without working, its steam room as well as the steam pipe is of course filled with common air instead of with steam; wherefore the steam which is at first generated in the said boiler, instead of being steam only, is a mixture of steam and air. Accordingly when steam is at first turned into my apparatus, a small cock with which the latter is provided is simultaneously opened for the purpose of allowing an escape for that air which otherwise would to a certain extent interfere with the condensation of the steam, and retard the boiling of the sea water in my evaporator. In conformity with this practice, as soon as the steam from the ship's boiler was turned into both apparatuses, (Sir T. Grant's and mine,) the small cock above alluded to was opened, whereupon a rush of air escaped through it as usual; but I then observed for the first time that this air escaping from my cold apparatus, (for no steam had as yet come into) instead of being mingled with atmospheric air, was an influent atmosphere, which, being brought in contact with a lighted lamp, burnt with a thin bluish flame, due evidently to the presence of carburetted gases resulting from the decomposing action exercised by the heated sur-
faces of the boiler, not only on the organic matters naturally contained in all natural waters, as discovered by the experiments which I made in 1850, and to which I have already alluded, but also on the fatty matters of the packings of the pistons, and introduced into the boiler by the feed pump, but in all probability principally from the decomposition of the melted tallow which is generally forced in it by means of a syringe ad hoc, for the purpose of preventing "priming," which introduction, in my humble judgment, is not under certain circumstances altogether free from danger.

I believe that most of the boiler explosions unsatisfactorily explained or absolutely unaccounted for are referable to the presence of the gases above alluded to, and of atmospheric air, in such proportions as to form a detonating mixture, which is then inflamed, possibly, by the unduly heated surfaces of the boiler above the water level, but in my opinion much more probably by the electricity resulting from the friction of the vesicular steam against the steam pipe and other surfaces. In effect, it is well known that the steam which issues from a boiler is always highly charged with electricity, and that electric sparks several inches in length may and have been drawn from it, especially when the boiler happens accidentally or otherwise to be isolated. On the other hand, a mixture of these gases may be exploded when mixed with atmospheric air, in certain proportions varying between 1 of the former and from 6 to 16 of the latter, the maximum effect being when 1 of carburetted hydrogen is mixed with 8 of atmospheric air. Given, therefore, the conditions of a sufficiently insulated boiler, and a mixture therein of the above-mentioned gas and atmospheric air in proportions ranging between one of the first and six, seven, eight, or nine of the second, an explosion of the boiler, of a more or less formidable nature, may take place.

I have already stated that sea water contains salt in the proportion of about 1 lb. to 33 lbs. of water. Now when sea water is evaporated, all the steam produced therefrom being of course fresh water, all the salt which that water contained is left behind; that is to say, the salt previously contained in the evaporated portion is left in that portion which is not yet evaporated, and which is therefore more impregnated with salt than before. If this salt be not removed, and the evaporation is continued, it goes on accumulating, furring and incrusting the vessel, and very soon destroys it. This is, in fact, an inconvenience common not only to all the sea-water stills hitherto contrived, but to the boilers of marine engines; for no boiler is safe from incrustation as soon as about one half of the sea water admitted into it has been evaporated; that is, as soon as the sea water has been saturated by concentration so as to contain 1 lb. of salt in about 16 lbs. of water.

My apparatus is not liable to these incrustations or deposits of salt, because the sea water circulates in it in a constant and uninterrupted manner, a discharge taking place at the same time through cock 15, (see fig. 685,) so as to leave the sea water in the apparatus superabundantly diluted to hold in perfect solution the whole of its salt; in fact, the sea water discharged through that cock contains only about one half per cent. more salt than it did when it first entered the apparatus, which is a perfectly insignificant increase.

The different parts of the apparatus being made of sheet, riveted, galvanized iron plates and of cast iron, connected in a substantial manner by screws and bolts, without soldering or brazing of any kind or in any part, it is perfectly impossible that it should go out of order by any accident short of those cases of force majeure which, unfortunately, are often the cause of the ruin of the ship itself.

I shall now give a description of the figs. 685 and 686, in which the same numbers represent the same organs. Fig. 685 is a section on the same plane, showing the mode of action of the apparatus, without reference to the real position of its constituent parts. Fig. 686 is a correct front elevation of the apparatus.

1. shows the large entrance tube for the sea water; this tube is connected to a large cock, communicating with the sea through the side or bottom of the ship; or else flanged to a much smaller pipe connected with a pump, by means of which the apparatus is supplied with water from the sea, which thus penetrates into the refrigerator 3, through the tube of communication 4, and thence passes round the sheaf of pipes 15, in the said refrigerator, through another communication tube 5, into the condenser 6, as shown by the arrows, and up the large vertical tube 8, whence the surplus sea water pumped up flows away through the pipe 9, in the direction indicated by the arrows. The condenser 6 being thus completely filled up with sea water, on opening the cock 10, the sea water passing through pipe 11 falls into the feed and priming box 12, and thence through pipe 13 into the evaporator 14, filling it up to a certain level, regulated by opening or shutting the cock 10 so as to maintain the sea water at the proper level in the evaporator 14.

2. Refrigerator. It is a horizontal case pervaded with pipes, 15, placed horizontally in it. The sea water, being introduced into this refrigerator, circulates round a sheaf of pipes 15, held between the caps 16, at each end of the said refrigerator, so that the fresh water which has been condensed in the pipes 23 of the evaporator 14, and in the pipes 17 of the condenser 6, is thereby cooled down to the temperature of the sea water outside.

3. a large pipe connecting the pipe 1 with the refrigerator 3.

4. large pipe connecting the refrigerator 3 with the condenser 6.
6. Condenser. It is a cylinder containing a sheaf of pipes 17, into which the non-aerated steam from the evaporator is condensed by the sea water which surrounds them.

7. Large outlet tube, used only when the apparatus is put below the level of the sea.
8. large upright tube, which, when the apparatus is placed on deck, is turned upward, and is of such a length that the sea water which is forced through the apparatus by means of the pump, or otherwise, may be raised a few feet above the whole apparatus, so that there may be in the large tube a column of sea water higher than the condenser 6, in order to keep it quite full.

9. overflow pipe for the escape of the excess of sea water.
10. cock of the feed pipe.
11. feed pipe, one end of which is inserted in the condenser 6, and the other end in the feed and priming box 12. It is through this feed pipe 11 that the sea water is fed from the top of the condenser into the feed and priming box 12, by opening the cock 10 to a suitable degree, as said before, 1.

12. feed and priming box. It is a box into which, on opening the cock 10, the sea water supplied from the condenser 6, by pipe 11, passes through pipe 13 into the evaporator 14, which is thus fed with the proper quantity of sea water. This feed box receives also any priming which might be mechanically projected by or carried along with the steam through pipe 22. In such a case the priming is then returned to the evaporator 14, through pipe 13.
13. feed pipe leading to the sea water to be evaporated into the evaporator 14.
14. Evaporator. It is a cylinder containing a sheaf of pipes 29, with their caps, 24, at each end, immersed in the sea water, part of which is to be evaporated.
15. sheaf of pipes of the refrigerator 3, for the purpose of cooling the fresh water produced; has already been described under No. 3.
16. caps of the refrigerator 3, so arranged that by means of the divisions reserved in the said caps, the steam from the boiler, and that evolved from the evaporator 14, are both made to travel to and fro through the different pipes 15 consecutively, so as eventually to flow out in a mixed and cold state through the cock 32, into the filter 33, and finally through the tube 34 in a perfect state.
17. sheaf of pipes placed between the two caps 18 of the condenser 6, for the purpose of condensing the aerated steam from the evaporator 14.
18. caps covering the ends of the sheaf of pipes 17 placed in the condenser 6.
19. aerating pipe, leading the air which separates from the sea water round the pipes 17 of the condenser 6 into the steam room or chamber of the evaporator 14. It is by means of this aerating pipe that the fresh water condensed in the condenser 6 becomes aerated, and this aeration is accomplished as follows:—

As the steam from the evaporator 14 enters the pipes within the condenser 6 at the top thereof, through the pipe 21, it follows that the sea water at the top of the condenser 6 is brought, as was already said under No. 11, to a temperature which, at the top of the said condenser, is as high as 200° or 208° Fahr.; this temperature, as we also said, No. 11, gradually diminishes from the top downward, but at a zone corresponding to about the point marked by No. 7, the temperature of the sea water round the sheaf of pipes 17 is reduced to about 140° Fahr. As the air naturally contained in the sea water begins to separate therefrom at about 190° Fahr., that in the sea water round the sheaf of pipes 17, between No. 7 and the top of the condenser, becoming entirely liberated, ascends, by virtue of its lighter weight, to the top of the said condenser 6; it then passes through the aerating pipe 19, and is then poured into the steam room 37 of the evaporator 14, wherein it mixes with the secondary steam therein produced by the evaporating pipes 23. This mixture of air and steam passes then through pipes 22 into the feed and priming box 12, and thence through pipe 21 into the sheaf of pipes 17. The air being there absorbed during the condensation of this secondary steam, with which it was mixed, the condensed fresh water resulting therefrom becomes thus super-aerated, and in passing subsequently through the cock 39 of pipe 30 into a portion of the pipes 15 of the refrigerator 3, it mixes there with the non-aerated fresh water, resulting from the steam of the boiler, which has condensed in the pipe 23 of the evaporator 14, which condensed water flows through pipe 25 into the steam trap 26, thence along pipes 29 and 31, and through the cock 41, into the other portion of pipes 13 of the refrigerator 3. The condensed water from the pipes 23 of the evaporator 14 becomes aerated by the excess of air contained in the condensed water of the pipes 17 of the condenser, in its passage with the latter through the pipes 15 of the refrigerator 3, in traversing which the combined waters are cooled down to the temperature of the sea water round the said sheaf of pipes in the refrigerator. And the result is, that after passing through the filter, it flows at 34 in the state of perfectly cold fresh water, thoroughly aerated, and of matchless quality.
20. level to which the sea water rises in the aerating pipe 19.
21. pipe conducting the mixture of steam and air from the feed and priming box 12 into the sheaf of pipes 17 of the condenser 6.
22. pipe leading the mixture of steam and air from the evaporator 14 into the feed and priming box 12, where any salt water, with which it may be mixed, is arrested and returned to the evaporator 14, through pipe 13, while the pure steam, passing through pipe 21, is next condensed in the sheaf of pipes 17 of the condenser 6.
23. Sheaf of pipes immersed in the sea water 36 of the evaporator 14, and in which pipes the steam coming from the boiler through the steam pipe 35 is condensed, after which it flows as distilled but non-aerated fresh water into the lower cap 24, and thence through pipe 25 into the steam trap 26, thence through pipes 29 and 31 and cock 41 into the sheaf of pipes 15 of the refrigerator 3.

24. Upper and lower caps covering the two extremities of pipes 23 of the evaporator 14, into which pipes the steam from the boiler diffuses itself, and is condensed, after which it flows in the state of distilled but non-aerated fresh water, through pipe 26 into the steam trap 26, and thence through pipes 29 and 31 into the pipes 15 of the refrigerator 3, in which it mixes with the aerated water coming through pipe 30, and passing through pipe 32 into the filter 33, finally issues at pipe 34 in the state of cold, matchless, aerated fresh water, immediately fit for consumption.

23. Pipe for the exit of the condensed non-aerated fresh water from the sheaf of pipes 23 of the evaporator 14; which water, after entering the steam trap 26, issues therefrom through pipe 29, and then enters the refrigerator as already said.

26. Steam trap. It is a box containing a float 28, provided with a plunger acting in such a way that when the box contains only steam, or a quantity of condensed water, not sufficient to buoy the float, it (the plunger) forces the exit pipe 29; but as soon as the condensed water has accumulated in quantity sufficient to buoy the float, up, the plunger, of course, rising with the float, no longer obstructs the exit pipe 29, and accordingly the condensed water may then escape as fast as it is produced.

27. Small pet cock on the top of the cover of the steam trap 26.

28. Float already described, (26.)

29. Pipe leading the condensed non-aerated water from the steam trap 26, through pipe 31, into the pipes 15 of the refrigerator 3, in which it mixes with the aerated fresh water from the condenser.

30. Pipes leading the condensed aerated water from the pipes 17 of the condenser 6, into the pipes 15 of the refrigerator 3, in which it mixes with the non-aerated water from the steam trap 26. This pipe is provided with two cocks, 38 and 39, for the purpose of cleaning the condenser 6.

31. Pipe leading the condensed non-aerated water from pipe 29 into the pipes 15 of the refrigerator, in which it mixes with the aerated water from the condenser.

32. Exit pipe and cock, through which the mixed distilled waters (aerated and non-aerated,) after passing through the pipes of the refrigerator, enters the filter 33.

33. Filter for receiving the condensed water from both the evaporator and the condenser, as they issue in a mixed and cold state from the pipes 15 of the refrigerator 3, through cock and pipe 32.

34. Pipe for the final exit of the perfect aerated fresh water.

35. Steam pipe and cock leading the steam more or less under pressure from any description of boiler to the pipes 23 of the evaporator 14. It is connected at one end with the steam boiler, and at the other with the upper cap 24 of the evaporating pipes 23.

36. Sea water, to be evaporated by the steam pipes 23, of the evaporator 14.

37. Steam room, or space into which the air naturally contained in the sea water used for condensation in the condenser 6, is poured through the aerating pipe 19, so as to mix with the steam generated by the pipes 23 of the evaporator.

38 and 39, two cocks on pipe 30, placed between the condenser 6 and the refrigerator 3, for the purpose of cleaning the pipes 17 of the condenser 6.

40 and 41, two cocks placed on pipe 31, for the purpose of cleaning the pipes 23 of the evaporator 14 and steam trap 26.

42. Cock placed between the cap 16 of the refrigerator 3, and the cock 32, for the purpose of cleaning the pipes 15 of the refrigerator 3.

43. Glass water-gauge.

44. Breathing pipe. It is a small pipe, one end of which is in communication with the lower cap 18 of the condensing pipes 17, and the other end is open to the atmosphere. The object of this pipe is not only to remove pressure from the cylinders, but likewise to afford an exit for the excess of air generated.

45. Brine cock.

46. Opening reserved in the feed and priming box. The first thing to be done is, of course, to change the apparatus with sea water. This is done by establishing a communication between the apparatus and the sea water round the ship. This is easily done by turning on the large cocks, or Kingston valves, connected with the large orifices 2 and 7, (see the figures;) whereupon the salt water immediately fills up both the refrigerator 3 through the passage 4 and the condenser 6 through the passage 5, up to a certain point (20) of the aerating pipe.

Opening now the cock 10 of the feed pipe 11, the sea water will pass from the condenser 6 into the feed and priming box 12, and thence through pipe 13 into the evaporator 14, where it should be allowed to rise up to about one third of the glass gauge 43, when the
WATER, SEA. 1087

cock 10 should be shut up. The apparatus being thus charged with its proper quantity of sea water; the steam boiler being ready to furnish the necessary steam; and admitting, of course, that the steam pipe 22 is in communication with the said boiler, the next thing to be done is to open the steam cock 35, shutting at the same time the cocks 39, 41, and 52, and opening cocks 38, 40, and 42, and likewise the small pet cock 27 of the steam trap 26. On opening this small pet cock 27, nothing but air will at first rush out; but, presently, steam will issue from it; it should then be closed more and more gradually as the steam is seen issuing from it with rapidity; and it should eventually be left almost, but not altogether, shut up, so as to leave only room for the smallest possible wreath of steam slowly to issue from it. As soon as the steam cock 35 is open, the steam from the boiler will rush through that cock into the shaft of pipes 23 of the evaporator 14, in which pipes it will be condensed by the sea water which surrounds them, and it will then flow in the state of condensed non-aerated distilled water through the pipe 25 into the steam trap 26; lift up the float 28, and passing through pipe 29, will flow through cock 40, its further progress being intercepted by cock 41, which is shut, as said before. As soon as the condensed water flows out in a clear state from cock 40, shut it, and open cock 41, so that it may pass into the pipes 15 of the refrigerator 3, and out at cock 42. In a few moments the condensed water will flow out in a clear state from that cock 42, which should then be closed, opening the same time cock 32, so that it may pass into the filter 33.

But the steam within the shaft of pipes 25 of the evaporator 14 soon brings the sea water round them to the boiling point, and converts part of it into steam. This pure secondary steam from the evaporator, issuing then from the priming box 12, passes through pipe 21 into the pipes 17 immersed in the salt water of the condenser 6, and being condensed in the said pipes, is allowed to flow out at the cock 38 which has been opened at starting the apparatus. In a short time, however, it will flow out from that cock 38, in a perfectly clear state; when this takes place shut this cock 38, and open cock 39, whereupon it will flow into the pipes 15 of the refrigerator 3, in which pipes it will mix with that coming from the pipes 23 of the evaporator 14, and flow with it through the said pipes 15, and thence into the filter 33 through the cock 32, the whole issuing finally from the filter 33 through pipe 34, in the state of perfect aerated fresh water.

From this brief description of my marine fresh-water apparatus it may be seen that a quantity of fresh water is produced always double that which can be evaporated from any boiler whatever, and indeed by increasing the number of evaporators 1 lb. of coal may thus be made to yield 30 or 40 lbs. of fresh water of matchless quality; that the small volume of the apparatus, the large quantity of fresh aerated water which it produces,* at an extremely small cost, its perfect safety, permanent order, and the ease 6th which it can be disconnected and all its parts reached, not only render it preeminently suited to naval purposes, but likewise to such stations or places as are deficient in one of the first necessities of life, salubrious fresh water, or where it cannot be obtained at all, or only in an insufficient, precarious, or expensive manner.—A. N.

The following letters were addressed to the Editor in reply to an inquiry made by him as to the value of Dr. Normandy's invention.

"Government Emigration Board, 8 Park Street, Westminster, 1st March, 1859.

"Sir,—I am directed by the Emigration Commissioners to acknowledge the receipt of your letter of the 25th ultimo, requesting to be furnished with any evidence they may possess as to the good or ill effects of the use of Dr. Normandy's distilled water on board emigrant ships.

"In reply, I am to acquaint you that the Commissioners have placed on board several of their emigrant ships, Dr. Normandy's apparatus for distilling fresh from salt water, and that the reports which they have as yet received from their surgeons in those vessels (who are instructed to pay particular attention to the matter) are uniformly of a favorable character—one gentleman only having mentioned that the water had at first an insipid taste which subsequently went off. This probably arose from some accidental circumstance in the particular machine, as freedom from insipidity is one of the main characteristics of the water.

"I enclose, for your information, extracts from the official reports made to this Board by their surgeons and the colonial immigration agents, respecting the quality of the water and its effects.

"Robert Hunt, Esq.

"S. Walcott, Secretary."

Extract from the report of Dr. Duncan, Immigration Agent, on the ship "Confinse," dated Port Adelaide, Jan. 19, 1859:

"A distilling apparatus, invented by Dr. Normandy, was sent out in the 'Confinse' to test its efficiency.

"There are two great objections to water distilled in the ordinary manner; the first is, that water thus obtained is without air, is unpalatable and indigestible; the second is, that it contracts, while in the process of distillation, an enervating odor and taste; in fact, ordinary distilled water is said to be indigestible and nauseous.

"These two objections appear to be perfectly met by Dr. Normandy's invention; the water obtained by his process is perfectly palatable, well aerated, and devoid of smell.

"Dr. Duncan, in his report of the 'Confinse,' states that the next time 20,000 lbs. of water were distilled, and is reported by the surgeon superintendent to have been of most excellent quality, and preferred by the emigrants to the water shipped on board in casks."

"An apparatus 4 ft. 6 in. high, 3 ft. long, and 2 ft. wide, produces at least 24 gallons of fresh water per hour."

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* An apparatus 4 ft. 6 in. high, 3 ft. long, and 2 ft. wide, produces at least 24 gallons of fresh water per hour.
WEAVING BY ELECTRICITY.

Extract from the Report of Dr. Carroll on the ship "Conway," dated Melbourne, Sept. 29, 1858:—

"The quality of the water produced was, in my opinion, excellent, and most agreeable in taste; and, so far as my observation went, most wholesome; in fact, during the hot weather I considered it quite a luxury; and I regretted much that the quantity produced was not greater. It was also preferred by the passengers to the ship's water."

Extract from the Report of Dr. Crane on the ship "Forest Monarch," dated Sidney, Jan. 5, 1859:—

"The condensed water was very good, excelling in clearness and purity, and much more palatable than any water I had ever previously seen on board ship, being not unlike the rain water so much esteemed in the West Indies. The water, as it came from the apparatus, possessed a slight peculiar taste, which varied in degree with the purity of the sea water employed in its production, and which disappeared on exposure to the air. This peculiar taste I attribute partly to the excessive evaporation of the condensed water, as I have noticed a similar taste in soda water that has been subjected to championship's sake, with common air, and partly to hypobromic products obtained from the destructive distillation of organic impurities contained in the sea water subjected to distillation."

Extract from the Report of Dr. Rivers on the "Moree shire," dated Calcutta, May 18, 1859:—

"The emigrants did not at first like the distilled water, but gradually got accustomed to it, and afterward to prefer it to the ordinary water. Those drinking it seemed better in health than the people using the other water, and more free from bowel complaints. I would, therefore, strongly recommend to all vessels prepared from Dr. Normanby's apparatus to be used in all ships carrying Coooles, as, in my opinion, it is not only wholesome, but perfectly free from all impurities, besides not so liable to disorder the bowels as the common water."

Extract from the Report of Mr. James Croxley, Immigration Agent at British Guiana, on the ship "Queen of the East," dated British Guiana, Oct. 19, 1859:—

"I found also Dr. Normanby's admirable distilling apparatus in full operation. It is almost impossible to speak in too favorable terms of this apparatus, capable of producing five hundred gallons a day—without the consumption, I think, of only eight bushels of coals—of water apparently as pure and wholesome as could be drunk, and taken from alongside the ship, from the muddy and impure water of the Demerara river."

Extract of a letter from Dr. L. S. Crane, surgeon superintendent of the ship "Devonshire," dated Cococoua, Dec. 27, 1859:—

The "Devonshire" was dismantled in a hurricane, by which the apparatus on deck was injured.

"Since the water apparatus was broken, the health of the Coooles has deteriorated. After careful observation, I find no other cause for the dysentery and diarrhoea prevailing than the water they drink. The ventilation is excellent, the between-decks have been kept beautifully clean and dry—the food is good and well cooked. The rice (cargo) has been staying too certain extent, but the diseases that arise from bad air—low fevers and cholera—have not made their appearance. Besides, the crew have suffered very much more than the Coooles, and the only condition common to both is the water they drink."

Extract of a letter from Mr. C. Chapman, surgeon superintendent of the ship "Euzine," to E. Waldo, Esq., dated Melbourne, Jan. 29, 1860:—

"In my opinion, the water it (Dr. Normanby's apparatus) produces is perfectly sweet and wholesome; is far preferable, and preferred by all hands, to the water in tanks or casks."

WEAVING BY ELECTRICITY. The article Weaving, and those referred to from it, together with the article on the Jacquard loom, will render the conditions necessary to the production of figures in any textile fabric tolerably familiar. A brief notice of a new invention for employing electricity in weaving cannot fail to be interesting. So long ago as 1852, M. Bonelli constructed an electric loom, which was exhibited at that time in Turin, but the first trial to which the machine was submitted gave but small hope to those who saw that the inventor would succeed in his object. The public trial at Turin, in 1855, in the presence of manufacturers, was not so successful as to remove all doubts as to the merits of the novel apparatus. In the following year it was submitted to the judgment of the Academy of Sciences at Paris, who appointed a committee to examine it, but it is believed that no report was ever made. In 1855, a model of the loom had a place at the Universal Exhibition at Paris, but the lateness of its arrival prevented any official report being made in reference to its merits. Since then, M. Bonelli has devoted much time and attention in endeavoring to remedy its defects and to perfect its working, so as to render it capable of holding its place in the factories. This M. Bonelli believes he has at last accomplished, and he has brought over to this country, not merely a model, but a loom in complete working order, which he is prepared with confidence to submit to the judgment of manufacturers, as a machine which, from its economy and efficiency, may be put in favorable comparison with the Jacquard loom. In the first place, it must be understood that the special object of M. Bonelli's machine is to do away with the necessity for the Jacquard cards used to produce the pattern at the present time, the source of delay and very considerable cost, more especially in patterns of any extent and variety of treatment. M. Bonelli uses an endless band of paper, of suitable width, the surface of which is covered with tin foil. On this metallized surface, the required
pattern is drawn, or rather painted with a brush in black varnish, rendering the parts thus covered non-conducting to a current of electricity. This band of paper, bearing the pattern, being caused to pass under a series of thin metal teeth, each of which is in connection with a small electro-magnet, it will readily be conceived that as the band passes under these teeth a current of electricity from a galvanic battery may be made to pass through such of the teeth as rest on the metallic or conducting portion of the band, and from such teeth, through the respective coils, surrounding small bars of soft iron, thus rendering them temporary magnets, whilst no current passes through those connected with the teeth resting on the varnished portions. Thus, at every shift of the band, each electro-magnet in connection with the teeth becomes active or remains inactive according to the varying portion of the pattern which happens to be in contact with the teeth. In a movable frame opposite the ends of the electro-magnets, which, it should be stated, lie in a horizontal direction, are a series of small rods or pistons, as M. Bonelli terms them, the ends of which are respectively opposite to the ends of the electro-magnets. These pistons are capable of sliding horizontally in the frame, and pass through a plate attached to the front of it. When this frame is moved so that the ends of the pistons are brought into contact with the ends of the electro-magnets, they are seized by such of them as are in an active state, and on moving the frame forward, those are retained while the others are carried back with it, and, by means of a simple mechanical arrangement, become fixed in their places; thus there is in front of the frame a plate, with holes, which are only open where the pistons have been withdrawn, and this plate, as will be readily understood, acts the part of the Jacquard card, and is suitable for receiving the steel needles which govern the hooks of the Jacquard in connection with the warp threads as ordinarily used.

The ordinary Jacquard cards are shown in the following wood-cut, fig. 687.

Instead of this arrangement, which will be understood by reference to the article Jacquard, M. Bonelli, as we have said, instead of the cards prepares his design on metal foil, in a resins ink, which serves to interrupt the current, and thus effect the object of the machine.

Figs. 687 and 688 explain generally the arrangements by which the process is effected. A, fig. 688, represents the plate pierced with holes, which plays the part of the card. Each of the small pistons or rods b, forming the armatures of the electro-magnets c, has a small head, d, affixed to the end, exactly opposite the needles e, fig. 687, of the Jacquard, and are capable of passing freely through the holes of the plate A, fig. 688. At a given
moment the plate is slightly lowered, which prevents the heads of the pistons passing, and the surface of the plate then represents a plain card. The pistons are supported on a frame, \( ff \), which allows them to move horizontally in the direction of their length. At each stroke of the shuttle, the frame, carrying with it a plate, \( A \), has, by means of the tendle, a reciprocating motion backward and forward, and in its backward movement presents the ends of the pistons to one of the poles of the electro-magnets, and, by means of certain special contrivances, contact with the magnets is secured. When the frame \( ff \) returns with the plate \( A \) toward the needles of the Jacquard, the electro-magnets, which become temporarily magnetized by the electric current, hold back the pistons, the heads of which pass through the plate \( A \), and rest behind it. On the other hand, the electro-magnets which are not magnetized, owing to the course of the current being interrupted, permit the other pistons to be carried back, their heads remaining outside the plate and in front of it. At this moment, the plate, by means of an inclined plane beneath it, is lowered slightly, thus preventing the heads of the pistons passing through the holes, by the edges of which they are stopped, so as to push against the needles of the Jacquard; on the other hand, the heads of the pistons which have passed within and to the back of the plate, leave the corresponding holes of the plate free, and the needles of the Jacquard which are opposite to them are allowed to enter.

The electro-magnets are put into circuit in the following manner:—One of the ends of the wire forming the coil of each of the magnets is joined to one common wire in connection with one of the poles of a galvanic battery. The other end of the coil wire of each magnet is attached to a thin metallic plate, \( m \), having a point at its lower extremity. All these thin metallic plates are placed side by side, with an insulating material between them, formed like the teeth of a comb, \( n \ n \). At a given time these thin plates rest with their lower extremities on the sheet bearing the design \( r \), which, in the form of an endless band, is wrapped round and hangs upon the cylinder \( q \), and according as the thin metal plate rests on a metallicized or on a non-conducting portion of the design, the corresponding electro-magnet is or is not magnetized, and its corresponding piston does not or does press against the needle of the Jacquard. The wire from the other pole of the battery of course communicates with the band bearing the design, by being attached to a piece of metal, which lies in constant contact with the metallic edge of the band. At \( b \) is a contact-breaker, which is put in motion by the movement of the frame. Besides this, by means of a mechanical arrangement connected with the tendle, which raises or depresses the griff frame, the band bearing the design is carried forward at each stroke, and the rapidity with which it is made to travel can readily be regulated, by means of gearing, at the will of the workman. By regulating the speed of the band, and by the use of thicker or thinner web, an alteration in the character of the woven material may be made, whilst the same design is produced, though in a finer or coarser material.

Such are the arrangements by which the loom will produce a damask pattern, or one arising from the use of two colors, one in the warp and the other in the weft. I will now shortly explain the method adopted by M. Bonelli for producing a pattern where several colors are required.

The design is prepared on the metallized paper, so that the colored parts are represented by the metallized portion of the band, but each separate color is, by removing a very thin strip of the foil at the margin, insulated from its neighboring color. Then all the pieces of foil thus insulated, which represent one color or shade, are connected with each other by means of small strips of tin foil, which pierce through the paper and are fastened at the back, and are conducted to a strip of tin foil which runs along the edge of the band, there being as many such strips of tin foil as there are colors. Thus each special color of the pattern, in all its parts, is connected by a conductor with its own separate strip of tin foil, and by bringing the wire from the pole of the battery successively into contact with the several strips, a current of electricity may be made to pass in succession through the several parts of the design on the band representing the separate colors of the design. Thus, assuming four colors, 1, 2, 3, 4, there would be four strips of tin foil running the length of the band, insulated from each other, each of which would be in connection with its own separate color only. At any given moment, the thin plates of metal resting on the pattern would touch it in a line which, as it passes over the width of the pattern, would run through all, or any one or more of the colors, but the electric current would pass only through those plates which rest on the one color represented by the strip with which the pole of the battery at that instant happened to be in contact.

The inventor claims the following as the results of his invention:—

First.—The great facility with which in a very short time, and with precision, reductions of the pattern may be obtained on the fabric by means of the varying velocity with which the pattern may be passed under the teeth.

Second.—That without changing the mounting of the loom or the pattern, fabrics thinner or thicker can be produced by changing the number of the weft, and making a corresponding change in the movement of the pattern.
Woad.

Third.—The loom and its mounting remaining unchanged, the design may be changed in a few minutes by the substitution of another metallized paper having a different pattern.

Fourth.—The power of getting rid of any part of the design if required, and of modifying the pattern.

Wire Rope. The manufacture of ropes made of wire, has, of late years, become a most important one. Not only are ropes of this description now employed in the most extensive coal mines of this country, and for winding generally, but they are used for much of the standing rigging of ships, and for numerous ordinary purposes. Perhaps the most important application of wire rope has been, however, in the construction of the electric cables. See Electro-telegraphy.

The following Tables show the relative values of ropes of hemp, iron, and steel.

**Table I.**

**Round Wire Ropes, for inclined planes, mines, collieries, ships’ standing rigging, &c.**

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<thead>
<tr>
<th>Hemp</th>
<th>Iron</th>
<th>Steel</th>
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<tbody>
<tr>
<td>Circum-</td>
<td>lbs. weight per fathom.</td>
<td>lbs. weight per fathom.</td>
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<td>2.5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3.5</td>
<td>4</td>
<td>1</td>
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<tr>
<td>4.5</td>
<td>3</td>
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</tr>
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<td>12</td>
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<td>10</td>
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</table>

**Table II.**

**Flat Wire Ropes, for pits, hoists, &c., &c.**

<table>
<thead>
<tr>
<th>Hemp</th>
<th>Iron</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size in inches</td>
<td>lbs. weight per fathom.</td>
<td>lbs. weight per fathom.</td>
</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 x 1</td>
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<td>1</td>
</tr>
<tr>
<td>2 x 1</td>
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</tr>
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<td>3 x 1</td>
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</tr>
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</tr>
<tr>
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</tr>
</tbody>
</table>

WOAD (Vonöë, Pastel, Fr.; Waid, Germ.; Gualdo, It. Isatis tinctoria, Linn.) is almost the only plant growing in the temperate zone which is known to produce Indigo. It is an herbaceous, biennial plant, belonging to the natural order cruciferae, and bears yellow flowers and large flattened seed vessels, which are often streaked with purple. The leaves, which are the only part of the plant employed in dyeing, are large, smooth, and glaucous, like cabbage leaves, but exhibit no external indication of the presence of any blue coloring matter, which indeed, according to modern researches, is not contained in them ready formed. The plant called by the Romans glastum, with which, according to Pliny, the Britons dyed their skins blue, is supposed to be identical with woad. Before the introduction of
indigo into the dyehouse of Europe, wood was generally used for dyeing blue, and was extensively cultivated in various districts of Europe, such as Thrangia, in Germany; Languedoc, in France; and Piedmont in Italy. To these districts its cultivation was a source of great wealth. Beruni, a rich woad manufacturer of Toulouse, became surety for the payment of the ransom of his king, Francis I., then a prisoner of Charles V., in Spain. The term 
\textit{pays de cocagne}, denoting a land of great wealth and fertility, is indeed supposed to be derived from the circumstance that the woad balls, called in French 
\textit{cogues}, were manufactured chiefly in Languedoc.

The woad leaves were not employed by the dyer in their crude state, but were previously subjected to a process of fermentation, for the purpose of eliminating the coloring matter. The seed, having been sown in winter, or early spring, the plants were allowed to grow until the leaves were about a span long, and had assumed the rich glaucous appearance indicative of maturity, when they were stripped or cut off. The cropping was repeated several times, at intervals of five or six weeks, until the approach of winter put a stop to the growth of the plant. The leaves sent up in the succeeding spring yielded only an inferior article, (called in German 
\textit{Kampfpflanze},) and it was therefore customary to keep only as many plants until the following year as were required for obtaining seed, which, the plant being biennial, is only produced in the second year. The leaves, after being gathered, were slightly dried, and then ground in a mill to a paste. In Germany it was usual to lay this paste into a heap for about twenty-four hours, and then form it by hand into large balls, which were first dried partially in the sun, on lattice work or rushes, and then piled up in heaps a yard high, in an airy place, but under cover, when they diminished in size and became hard. These balls, when of good quality, exhibited, on being broken, a light blue or sea-green color. They were usually sold in this state to manufacturers, by whom they were subjected to a second process in order to render them fit for the use of the dyer. This process was conducted in the following manner:—The woad balls were first broken by means of wooden hammers, and the triturated mass was heaped up on a wooden floor, sprinkled with water, sometimes with a little wine, and allowed to ferment or putrefy. The mass became very hot, and emitted a strong ammoniacal odor, and much vapor. In order to regulate the process it was frequently turned over with shovels and again sprinkled with water. When the heat had subsided, the mass, which had become dry, was pounded, passed through sieves, and then packed in barrels ready for use. It had the appearance of pigeon's dung.

In France the paste obtained by pounding the woad leaves was taken to a room with a sloping pavement, open at one end, laid in a heap at the higher end of the room, and allowed to ferment for a period of twenty or thirty days. The mass swelled up and often showed cracks or fissures, which were always carefully closed as soon as they appeared, whilst a black juice exuded and ran away in gutters constructed for the purpose. When the fermented heap had become moderately dry, it was ground again and formed into cakes, called in French 
\textit{cogues}, which were then fully dried, and in this state brought to market. In France and Italy a second fermentation was not generally thought essential, but when performed it was conducted exactly in the manner just described.

At the present day wood is nowhere employed alone for the purpose of dyeing blue, since it is found more economical to use indigo, and the cultivation of the plant has therefore declined considerably, and has existed where it was formerly carried on extensively. By woollen dyers, however, it is still used, but only as a means of exciting fermentation, and thus reducing the indigo blue in their vats; indeed, the wood employed by them contains little or no blue coloring matter. See Indigo.

Numerous attempts have been made to extract the blue coloring matter from wood, in the same way that indigo is extracted from the leaves of the indigofera in the East Indies and other countries. At the commencement of the present century, when the price of indigo on the continent of Europe was very high, a prize of 100,000 francs was even offered by the French government for the discovery of a method of obtaining from the 
\textit{Indigofera tinto-}
\textit{raria, or some other native plant, a dyeing material, which, both in regard to price and the beauty and solidity of its color, should form a perfect substitute for indigo. The experiments which were made in consequence served to prove that it was quite possible to obtain genuine indigo from wood leaves, but that the process could never be carried on profitably, on account of the very small proportion of coloring matter contained in the plant. Nine parts of fresh leaves yield only one part of the prepared material or paste, and the latter does not afford more than 2 per cent, of its weight of indigo. According to Chevreul, the leaves of the 
\textit{indigofera and}, even when grown in the neighborhood of Paris, contain 50 times as much indigo blue as those of the 
\textit{Indigofera tinto-}
\textit{raria, and, when cultivated in tropical countries, the amount is probably still higher. The comparatively high price of land and labor would probably itself prove a sufficient obstacle to the successful manufacture of indigo in most European countries, even if the yield were equal to what it is in the tropics.

In 1808 Chevreul published the results of his analysis of woad and paste. It has more recently been made the subject of one of the investigations for the purpose of ascertaining the state in which indigo blue exists in plants and other organisms. See Indigo.—E.S.
ZINC.

ZINC, METALLURGY OF. Roasting of Ores.—Blende, or sulphide of zinc, is, previous to its treatment for metal, carefully roasted in a reverberatory furnace, over the bottom of which it is spread in a layer of about four inches in thickness. A strong heat is necessary for this purpose, and during the operation the charge is frequently stirred with a strong iron rake, with a view of exposing fresh surfaces to the gases of the furnace. The apparatus most commonly employed in this country for roasting sulphide of zinc consists of a reverberatory furnace about 30 feet in length and 9 feet in width, provided with a fireplace of the usual construction. The sole or hearth of this apparatus is divided into three distinct beds, of which that nearest the fire bridge is 4 inches lower than that which is next it, which is again 4 inches lower than that nearest the chimney. In addition to the heat derived from the fireplace, the gases escaping from the reducing furnaces are usually introduced immediately before the bridge, and a considerable economy of fuel is thereby effected. When the furnace has been sufficiently heated a charge of 12 cwt. of raw blende is introduced into the division nearest the chimney and equally spread over the bottom, care being taken to stir it from time to time by means of an iron rake, as before described. After the expiration of about eight hours this charge is worked on to the floor of the compartment forming the middle of the furnace, and a new charge is introduced into the division next the chimney. About eight hours after this charging the ore on the middle bed is worked on to the first, whilst that on the hearth next the chimney is equally spread on the middle one and a new charge introduced into the division next the stack. After the expiration of another period of eight hours the charge on the first hearth is drawn, the ore on the middle and third hearths moved forward, and a fourth charge introduced as before. In this way the operation is continuous, and each furnace will effect the calcination of about 30 cwt. of ordinary blende in the course of 24 hours.

Calamine, or silicate of zinc, is usually prepared for smelting by calcination in a furnace resembling an ordinary lime kiln, the heat being often supplied by means of four fireplaces arranged externally, and so placed that the heated gases may be drawn into it, and regularly distributed through the interstices existing between the masses of ore. Calamine subjected to this treatment commonly loses about one-third of its weight, and is at the same time rendered so friable as easily to admit of being reduced to fine powder by an ordinary edge-mill.

Reduction.

Belgium process.—When this method of treating zinc ore is employed, the furnace represented in fig. 689 is commonly used.

![Fig. 689 represents, on the left hand, a front elevation of the furnace, and on the right a sectional elevation through the ashpit and fireplace. f is the fireplace, whilst a is the cavity into which are introduced the retorts destined for the distillation of the metal.](image-url)
The products of combustion escape by the openings a into a flue, by which they are conducted into the caldarium for the purpose of economizing the waste heat. These furnaces are either arranged in couples, back to back, or in groups of four, for the purpose of rendering the structure more solid, and economizing heat. In the arched chamber a are placed 48 cylindrical retorts, 3 feet 6 inches in length from b to d, and 7 inches internal diameter. These are made of refractory fire clay, well baked and supported behind by ledges of masonry, a, b, fig. 690, whilst in front, at c, d, they rest on fire-clay saddles let into an iron framing. Short conical fire-clay pipes, 10 inches in length from d to e, are fixed in the mouths of these retorts by means of moistened clay, and project for a short distance beyond the mouth of the furnace. To these are adapted thin wrought-iron cones 18 inches in length from e to f, tapering off at the smaller extremity to an orifice of about three quarters of an inch in diameter. The inclined position of the retorts, the method of adjusting the pipes, and the general arrangement of the apparatus are shown in fig. 690, in which r, r, r, represent the nozzles of thin wrought iron. When a new furnace is first lighted the retorts are introduced without being previously baked, but care must be taken that they be perfectly dry and seasoned, and for this reason it is necessary to keep a large stock constantly on hand, in a store house artificially heated by means of some of the flues of the establishment. The heat is gradually increased during three or four days, at the end of which period charges of ore are introduced, the clay cones are luted in their places, and the furnace is brought into full working order. The charge of a furnace consists of 1,680 lbs. of roasted blende or calcined calamine, and 840 lbs. of coal dust. The ore and coal dust, after being finally divided and intimately mixed, is slightly dampened, and subsequently introduced into the retorts by means of a semi-cylindrical scoop, by the aid of which an experienced workman will effect the charging without spilling the smallest quantity of the mixture.

In this country the retorts in the lower tier are usually not charged, as they are extremely liable to be broken, and are therefore only employed to moderate the heat of the furnaces. On the Continent, however, the fireplace is frequently covered by a hollow arch, and in that case every retort requires a charge of ore.

The mixture introduced into the retorts varies, to a certain extent, with their position in the furnace, for in spite of every precaution to prevent inequality of temperature, it is found impossible to heat the whole of them alike, and those next the fire, therefore, from being the most strongly heated, are liable to work off first. As soon as the retorts have been charged the clay cones are luted into their places, and carbuncle oxide gas, which burns with a blue flame at the mouth of the cones, quickly makes its appearance. The quantity of this gas gradually diminishes, and as soon as the flame assumes a greenish-white hue, and white fumes are observed to be evolved, the sheet-iron cones are put on, and the furnace at once enters into steady action. From time to time, as the iron cones become choked with oxide, they are taken off and gently tapped against some hard substance, so as to remove it, and then replaced. The oxide thus collected is added to the mixture prepared for the next charge. After the expiration of about six hours from the time of charging the wrought-iron tubes are successively removed, and the metallic zinc scraped from the clay pipes into an iron ladle. This, when full, is skimmed, and the oxide added to that obtained from the nozzles, whilst the pure metal is cast into ingots, weighing about 25 lbs. each. At the expiration of twelve hours from the time of charging the zinc is again tapped, and the residue remaining in the retorts withdrawn. The retorts are immediately recharged, and the operation of reduction is conducted as above described.

The residue obtained from the retorts, after the first working, are passed through a crushing mill, mixed with a further quantity of small coal, and again treated for the metal they contain. The earthen adapters or cones, when unfit for further service, are crushed and treated as zinc ores.

In order to work these furnaces with economy, it is of the greatest importance that they should be constantly supplied with a full number of retorts, since the amount of fuel consumed, and the general expenses incurred for each furnace, will be the same if the apparatus has its full complement of retorts, or if one-half of them are broken and consequently disabled.

It is therefore necessary, in all zinc-smelting establishments, to keep a large stock of well-seasoned retorts, which, before being introduced into the furnace, to make good any deficiency caused by breakage, are heated to full redness in a kiln provided for that purpose. The Belgian process of zinc smelting is that which is at present most employed in this country. The principal localities in which zinc ores are treated are Swansea, Wigan, Llanelli, and Wrexham.

Silesian process.—In the sileon works of Silesia the furnaces employed differ considerably from those used in the Belgian process.

Fig. 601 represents an elevation, and fig. 602 a vertical section of the Silesian furnace. The distillation is effected in a sort of mantle of baked clay, \( m \), fig. 602, and figs. 603, 604, about 3 feet 3 inches in length, and 20 inches in height. The front of this mantle is
pierced with two apertures. The lower opening, $d$, serves to remove the residues remaining in the retorts after each operation, and is closed during the process of distillation by a small door of baked clay, firmly luted in its place. In the upper opening is introduced a hollow clay arm, bent at right angles, $a$, $b$, $c$, and which remains open at $c$. An opening at $b$ permits of charging the retort by means of a proper scoop, and this, during the operation, is closed by a luted clay plug. From six to ten of these muffles or retorts are arranged in rows, on either side of a furnace provided with suitable apertures for their introduction. They are securely luted in their places, and the openings closed by sheet-iron doors, by which the too rapid cooling of the pipe $a$, $b$, $c$ is prevented. The fuel employed is coal, which is burnt on the grate $a$, situated in the centre of the furnace. The retorts are charged with a mixture of calamine and small coal, or more frequently coke dust, since, when coal is employed, the products of distillation are found to be liable to choke the pipe $a$, $b$, $c$. The zinc escapes by the opening $c$ of the adapter, and is received into the cavities $o$ of the furnace.

The furnace shown in figs. 695, 696, 697, is for remelting the metallic zinc. Fig. 696 is a front view; fig. 695 is a transverse section, fig. 697 a view from above; $a$ is the fire-door; $b$ the grate; $c$ the fire bridge; $d$ the flue; $e$ the chimney; $f, f, f$ cast-iron melting pots, which contain each about 10 cwt. of metal. The heat is moderated by the successive addition of pieces of cold zinc. The inside of the pots is sometimes coated with loam, to prevent the iron being attacked by the zinc.

In some establishments, and particularly those at Stolberg in Prussia, the retorts have the form $b$, represented in fig. 698. $c$ is an adapter also of fire clay; $b$ a cone of wrought iron, and $a$ a small vessel of the same material for the collection of the oxide, and furnished in the bottom with an aperture for the escape of the gases generated.
ZINC.

These are arranged on either side of a grate as represented, fig. 699, an internal opening serving for two retorts, and of which there are usually twelve in each furnace. \( \xi \) is the fire door; \( \gamma \) grate; \( \alpha \) chamber in masonry of furnace; \( \eta \) diaphragm of fire brick supporting adapter, in the depressed part of which the metallic zinc is collected and subsequently removed by a scraper, as in the case of the cone of the Belgian retort. The wrought-iron vessel \( \delta \) is supported by a chain or wire \( \lambda \).

Fig. 700 represents a longitudinal elevation of the roasting furnace employed.

The general consumption of Spelter throughout the world is about 67,000 tons per annum, of which about 44,000 tons are made to take the shape of rolled sheets, and these are estimated to be applied as follows, each quantity being somewhat below the truth:

<table>
<thead>
<tr>
<th>Tons.</th>
<th>Roofing and architectural purposes</th>
<th>23,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ship sheathing</td>
<td>3,500</td>
</tr>
<tr>
<td></td>
<td>Lining packing cases</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>Domestic utensils</td>
<td>12,000</td>
</tr>
<tr>
<td></td>
<td>Ornaments</td>
<td>1,500</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous</td>
<td>1,500</td>
</tr>
</tbody>
</table>

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44,000

Fifteen years ago the quantity used for roofing did not exceed 5,000 tons; none was employed for ship sheathing or lining packing cases, and stamped ornaments in zinc date only from 1852.

From the low temperature at which zinc fuses, and from the sharpness of impressions possessed by castings in this metal, it is much employed on the Continent for the production of statues and statuettes. The uses of this metal in the preparation of alloys have already been noticed under the head of alloys. It is also employed like tin for coating iron, producing what is known as galvanized iron. The disinfectant liquor of Sir W. Burnett is chloride of zinc, and the oxide of this metal is much employed as a pigment in place of white lead. Zinc or Spelter imports in 1858:

<table>
<thead>
<tr>
<th>Tons.</th>
<th>Crude in cakes.</th>
<th>271</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Denmark</td>
<td>271</td>
</tr>
<tr>
<td></td>
<td>Prussia</td>
<td>9,034</td>
</tr>
<tr>
<td></td>
<td>Hamburg</td>
<td>8,413</td>
</tr>
<tr>
<td></td>
<td>Holland</td>
<td>1,200</td>
</tr>
<tr>
<td></td>
<td>Belgium</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>Other Parts</td>
<td>302</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19,519</td>
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</tbody>
</table>

Computed real value. £470,195.

Rolled, but not otherwise manufactured.

<table>
<thead>
<tr>
<th>Tons.</th>
<th>Denmark</th>
<th>47</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prussia</td>
<td>304</td>
</tr>
<tr>
<td></td>
<td>Belgium</td>
<td>3,818</td>
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<tr>
<td></td>
<td>Other Parts</td>
<td>37</td>
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<tr>
<td></td>
<td></td>
<td>4,206</td>
</tr>
</tbody>
</table>

Computed real value. £128,738.

THE END.
A supplement to Ure's dictionary of arts