The combination of hydrogen with *phosphorus* is also obtained by the decomposition of water, by boiling the phosphorus in a liquid alkali, which retains the phosphorus in a temperature sufficient for enabling it to effect the decomposition. The oxygen of the water unites with one portion of the phosphorus, and forms phosphoric acid; while at the same time the hydrogen unites with the other portion, and forms phosphureted hydrogen.

c. The combinations of *azotic gas* with the simple solid combustibles are not yet sufficiently understood, except its combination with carbon to form *cyanogen*[1], which is a compound of one atom of azote and two atoms of carbon.

The compound gases do not enter into many combinations with solids, if the salts, which the acid gases form with alkalies, earths, and metallic oxides, be excepted; and those formed by ammonia with the solid acids. In general they are rather decomposed. Thus, carbon, phosphorus, sulphur, and many metals decompose nitrous gas, nitric acid, and oxymuriatic acid; and sulphurous acid is decomposed by the metals.

Such are the effects of the combinations of solids, liquids, and gases. The knowledge of the laws which regulate them, and the results of the combinations, are of the utmost importance; the greater number of the operations of pharmacy consisting of the combination of substances, with a view either of obtaining compounds by their direct chemical union, or the products of chemical action resulting from their mutual decomposition.

SECTION III.

PHARMACEUTICAL OPERATIONS AND APPARATUS.

THE operations of pharmacy may be arranged under two classes: —

I. *Operations which are purely mechanical.*

II. *Operations which are performed by chemical powers and agents.*

The first are intended for determining the weight and bulk of bodies, diminishing their cohesion, and separating their in-

[1] This name was imposed upon this gaseous compound by Guy Lussac, who discovered it in 1815; and who found that, in combination with hydrogen, it forms Prussic acid, which he therefore named *hydrocyanic acid*. It may be obtained from exposing dry prussiate of mercury in a small retort to a moderate heat. It is a colourless, transparent, elastic fluid, with a strong, disagreeable odour, soluble in water and alcohol; and highly inflammable.

tegral parts: the second are intended for separating the elements of bodies from each other, and for reuniting these elements into new combinations.

I. PHARMACEUTICAL OPERATIONS PURELY MECHANICAL.

a. *Of the means of determining the weight and bulk of bodies.*

In pharmaceutical processes it is essential that the quantities of the substances employed be accurately ascertained; and for this purpose beams with scales, and measures must be provided. Several sets of beams and scales are necessary: one set for large weights, from one pound to one hundred weight or more; another for weights not exceeding five pounds; and a third for small weights under two drachms. A good beam should remain in equilibrium, both by itself, and when the scales are suspended to each extremity: the largest set should be exact to within half a drachm; the second should be sensibly affected by two or three grains at most; and the smallest by the hundredth part of a grain. Apothecaries, however, seldom have beams of such accuracy, and, generally, those that they employ are much injured by exposure to acid fumes, and from want of cleanliness. To preserve the delicacy of beams they should be kept in very close cases, and not left suspended longer than is absolutely necessary; nor should they be overloaded.

Drugs are bought in the gross by *avoirdupois weight*, which is the standard of most articles of merchandize; but for the composition of medicines *troy weight* is directed to be used by the British Colleges. The following TABLE exhibits the manner in which the pound is divided, and the signs used in prescription for denotiong the different weights.

A pound (*libra*), ℔	contains	Twelve ounces.
An ounce (*uncia*), ℥	contains	Eight drachms.
A drachm (*drachma*), ʒ	contains	Three scruples.
A scruple (*scrupulus*), ℈	contains	Twenty grains.
A grain (*grana*), gr.	contains	———

The differences between the avoirdupois pound and the troy or apothecaries' pound, and their subdivisions, are exhibited in the following Tables.

Apothecaries' weight.

Pound.		*Ounces.*		*Drachms.*		*Scruples.*		*Grains.*
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1	=	3	=	60
						1	=	20[1]

[1] Tables of the method of reducing the suodivisons of the troy pound into decimals of the troy pound are given in the Appendix to Part I.

Avoirdupois weight.

Pounds.		Ounces.		Drachms.		Grains.
1	=	16	=	256	=	7000
		1	=	16	=	437·5
				1	=	27·975

The troy weight has also been adopted by the Edinburgh College for apportioning liquids; but the London and Dublin Colleges with more propriety order liquids to be measured: and for this purpose the London College employs measures derived from the wine gallon, which is subdivided for medical purposes, in the manner exhibited by the following Table, which shows also the signs used for denoting the several measures.

A gallon (*congius*), cong.	contains	Eight pints.
A pint (*octarius*), O		Sixteen fluid ounces.
A fluid ounce (*fluid uncia*), f℥		Eight fluid drachms.
A fluid drachm (*fluid drachma*), fʒ		Sixty minims.
A minim (*minima*), ♏		

Table of the proportions of the wine gallon.

Gallon.		Pints.		Fluid Ounces.		Fluid Drachms.		Minims.
1	=	8	=	128	=	1024	=	61440
		1	=	16	=	128	=	7680
				1	=	8	=	480
						1	=	60

The London College have introduced the last measure as a substitute for the drop, the inaccuracy of which had been long experienced; as the fluidity and specific gravity of the liquid, the thickness of the lip of the phial, and even its degree of inclination, were all liable to vary its size: but by dividing the fluid drachm into sixty equal parts, a measure of bulk is obtained as constant and uniform as the grain weight employed for solids.

For measuring liquids graduated glass measures of different sizes are to be preferred; (PL. i. *fig*. 8, 9.) and for quantities under five minims a slender graduated glass tube, (PL. i. *fig*. 10.) open at both ends, is to be employed. When this tube is used, the graduated end is to be inserted into the liquid to be measured, down to the mark indicative of the quantity required; and the upper end being then closely covered by the finger, it is removed, retaining the proper quantity of liquid, which again drops from it on raising the finger from the upper end. In extemporaneous prescription the measures of a table-spoonful and a tea-spoonful are used when great accuracy is not required; the former being supposed to be equal to half a fluid ounce, the latter to a fluid drachm.

Elastic fluids or gases are also measured in glass jars, or tubes hermetically closed at one extremity, and graduated by inches with their decimals; but in ascertaining the bulk of gases, the temperature of the atmosphere, and its density at the time, as indicated by the thermometer and the barometer, must be attended to: for if the former be above or below 60°, the mean heat of the air, or if the mercury in the barometrical tube be under or above 30 inches, corrections must be made by calculation relative to the degrees of temperature and pressure. For the former, the observed column of air must be divided by 80 and the quotient multiplied by the degree of temperature above or below 60°. This correction is negative when the actual temperature is above the standard, and positive when below. For making the corrections with regard to pressure, see the table in the Appendix.

The SPECIFIC GRAVITY of bodies is also necessary to be known in many pharmaceutical processes; and as the effects of acids and alcohol depend on the degree of their concentration, a knowledge of their gravity enables this to be most correctly ascertained. The specific gravity of any substance is "the quotient of its absolute weight divided by its magnitude, or the weight of a determinate bulk of any body; and as a standard for this purpose, the weight of a determinate magnitude of distilled water has been generally assumed as [1]unity" It is seldom necessary to determine the specific gravity of solids; but for ascertaining that of fluids various means may be employed. If a little ball of rock crystal, for instance, suspended by a fine gold wire, be weighed first in air, and afterwards in distilled water, the weight lost by the ball is equal to the weight of an equal bulk of the liquid; so that by repeating this operation in other fluids, and dividing its loss of weight in any other liquid by its loss of weight in water, the quotient is the specific gravity of the particular liquid. The specific gravity of liquids,, however, is more generally determined by hydrometers, of which Mr. Nicholson's is by far the most accurate.[2]

The specific gravity of liquids is also very easily determined by the following simple method. Take a small light bottle which stands firmly, and holds about a fluid ounce or two of water, and stop its neck by a piece of barometer tube very accurately ground. First weigh the empty bottle and tube, then fill it with distilled water at 60° recently boiled, till the water

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[1] *Lavoisier's Elements of Chemistry*, —Trans. 376.
[2] *Nicholson's Journal*, 4to. i. 110.

rises a little into the bore of the tube, and weigh the whole, scratching the weight on the bottle, and also the weight of the empty bottle and tube. For facilitating calculation, the water should be brought to that height in the tube, at which its weight will be 500 grains, or 1000, or 1500 or 2000; and this height must be accurately marked on both sides of the tube with a file. By filling this bottle to the above mark with any other fluid, and weighing it, the specific gravity of that fluid is ascertained by only calculating how much lighter or heavier it is than the same bulk of water.[1]

In ascertaining specific gravity the substances should be brought by calculation to the temperature of 55°, if the thermometer be above or below that point at the time of performing the experiments; and the gravities should always be expressed according to their relation to distilled water. Although this is the method generally employed in philosophical and pharmaceutical operations, yet it is necessary to observe, that the strength of spirits, according to the Excise laws in this country, is estimated by the proportion they contain of a standard spirit, termed hydrometer proof, which consists of 40 parts of pure alcohol and 51 of water. Clarke's hydrometer[2], which is the one employed by the Excise, loaded with the proper weights, sinks to the mark indicating *proof* in spirits of the specific gravity 0·920, at a temperature of 60°. The strength of spirits stronger than proof, or *over proof*, is ascertained by the bulk of water required to reduce a given bulk of the spirits to the specific gravity denominated proof, on Clarke's hydrometer; and the strength of weaker spirits, or *under proof*, is estimated by the quantity of water it would be necessary to abstract to bring the spirits up to proof. Thus, if 20 gallons of the spirit require the addition of one gallon of water to bring it to proof, the spirit is said to be *one* to *twenty over proof*; and if, from the same quantity of spirit, one gallon of water must be abstracted to bring it to proof, it is said to be *one* in *twenty under proof*; and so on.

b. *Of the mechanical division of bodies.*

The cohesion of solid bodies often opposes an obstacle to their immediate chemical combination with other substances, and their medicinal action in the stomach; and therefore the following preliminary mechanical operations are instituted for overcoming to a certain degree that power, and separating the

[1] *Aikin's Dictionary of Chemistry*, ii. — *Appendix*.

[2] This instrument consists of a thin copper ball, terminating above in a flat stem, and below in a knob or metallic button to keep it perpendicular. It swims in alcohol, and there is a mark on the stem, with a weight marked *proof*, which when placed on the stem, with weights to suit the temperature, sinks it till the mark on the stem is on a level with the surface of the liquid.

integrant particles of bodies, or reducing them to the state of powder. These are denominated pulverization, trituration, levigation, and granulation.

1. *Pulverization* is that process by which friable and brittle solid bodies are reduced to powder. It is generally performed in mortars by means of pestles. These are made of various materials, of brass, iron, marble, granite, glass, agate, and porcelain, or of Wedgewood's ware, according to the nature of the substances for the pulverization of which they are intended to be used; it being requisite that the materials of which pestles and mortars are made be such as to resist both mechanical force and the chemical action of the substances they contain.

Mortars are required to be of various sizes. The largest are usually made of cast-iron, fig. 1. pl. i. fitted with wooden covers, perforated to admit the pestle, but close enough to prevent the finer and lighter parts of the substances from flying off, and to defend the operator from disagreeable and noxious matters, such as aloes, ipeccuanha, &c.: or this may be more completely attained by tying closely round the mouth of the mortar, and round the stalk of the pestle, a large piece of leather, so pliable as to permit the free motion of the pestle. But, notwithstanding these guards, it is sometimes necessary for the operator to cover his mouth and nostrils with a wet cloth, and to stand with his back to a current of air, that the particles which rise may be carried from him, when very acrid friable matters, as euphorbium or Spanish-flies, for instance, are to be powdered. To lessen the labour, the pestle is often attached by a cord to the end of a flexible wooden beam, placed horizontally over the mortar, the elasticity of which elevates the pestle to the proper height after each stroke is made. For lighter purposes, brass and bell-metal mortars are sometimes used; but as, in the pulverization of every hard body, the mortar also is worn by the operation, these mortars are improper for pharmaceutical purposes; neither must marble or metallic mortars be used for acid substances. The most useful mortars for smaller articles are those of Wedgewood's ware, as they are smooth, hard, and resist the action of any chemical re-agent.

Of whatever materials mortars are made, they should be internally of the form of a hollow hemisphere, and their sides should have such a degree of inclination as to make the substances fall back to the bottom every time the pestle is lifted. The operation, however, is retarded when too great a portion of the ingredients falls under the pestle; hence a large quantity of any substance should not be put into the mortar at a time, and the finer parts should be from time to time removed.

Vegetable matters require to be dried before they can be pulverized; and wood, roots, and barks should be previously cut, chipped, or rasped. When roots are very fibrous, as those of ginger, for example, it is advisable to cut them diagonally, which prevents the powders from being full of hair-like filaments. Resins and gum resins, which soften in a moderate temperature, or in warm weather, should be powdered in cold weather, and only gently beaten to prevent them from running into a paste instead of forming a powder; and when the powdered substance is intended to be dissolved in any menstruum, except a pure alkali, the pulverization is much facilitated by mixing them with a portion of clean well washed white sand. The pulverization of camphor is assisted by the addition of a few drops of alcohol; sugar is the best addition to aromatic oily substances, as nutmegs, mace, &c.; and to the emulsive seeds some dry powder must be added, without which they cannot be reduced to powder. Metals which are scarcely brittle enough to be powdered, and yet are too soft to be filed, as zinc, for instance, "may be powdered while hot in a heated iron mortar, or may be rendered brittle by alloying them with a small quantity of mercury[1];" but as metals are not required to be reduced to the state of very fine powder for pharmaceutical purposes, these processes are seldom performed.

2. *Trituration* is intended to produce the same effect as pulverization, but in a greater degree. It is performed by a rotatory motion of the pestle, either in the common mortars of glass, agate, or Wedgewood's ware, or in flatter mortars made of the same materials. On a great scale, this operation is performed by means of large rollers of hard stone, which turn upon each other as in corn-mills, or by one vertical roller turning upon a flat stone. The fine powders kept in the shops are generally ground in this manner; but there appears to be an error in reducing vegetable matter to the state of impalpable powder, as in this state, both during the process of grinding and afterwards, the air and light act powerfully upon them, and produce changes, which, although they be not well understood, yet appear to alter the medicinal virtues of the substances.

3. *Levigation* is a process similar to trituration, except that the rubbing is assisted by the addition of a liquid in which the solid under operation is not soluble. Water or spirit of wine is usually employed, and occasionally viscid and fatty matters, as honey and lard. The substance to be levigated is spread

[1] *Lavoisier's Chemistry*,—Trans. 437.

on a flat table of porphyry, or some other hard stone, pl. 1. fig. 4. and is then bruised and rubbed with a muller of the same materials, either of a pyramidal shape, as *a a*, fig. 4. pl. i. or a portion of a large sphere. A thin spatula of ivory, horn, wood, or iron, is employed to bring back the materials from the edges of the table, to which the operation of the muller continually drives them. Earths and some metallic substances are thus prepared.

4. *Granulation* is employed only for the mechanical division of metals and of phosphorus. It is performed by melting the substance, and either stirring it briskly till it is cold, or pouring it, in the melted state, into water, and stirring or agitating it till it cools. For the granulation of phosphorus the latter process only can be employed.

Substances are also reduced to the state of coarse powder by rasping and filing; and softer vegetable bodies are reduced to the state of pulp by means of the grater. Pl. i. fig. 6.

MECHANICAL SEPARATION.

The parts of substances, under certain circumstances, may be separated from each other by different mechanical means; as sifting, washing, or elutriation, filtration, expression, and despumation.

1. *Sifting*. The particles of the powders obtained by the longest and most accurate pulverization and trituration are still of very unequal degrees of fineness, and therefore require to be separated, the finer from the coarser, by the operation denominated sifting. The finer particles pass through the interstices of the sieves, which are made of iron-wire, or hair-cloth, or gauze, and leave the coarser to be again submitted to the pestle; and thus by degrees the whole is made to assume an uniform fineness. The simple sieve is a broad wooden hoop, with a cloth of one or other of the above textures stretched over it in the manner of the parchment of a drum: the compound sieve, which is more employed, consists of the simple sieve, with a deeper rim, pl. i. fig. 5. *c*; a lid *b* covered with leather; and a receiver *d*, with leather stretched across one end, and made sufficiently wide to admit the lower portion of the sieve to enter and fit tightly within it. When these are put together, the finest powders may be separated by them without any loss or inconvenience to the operator.

2. *Washing*, or *Elutriation*, is intended for separating the finer parts of powders prepared by trituration or levigation, which are not acted upon by water. The powdered substance is mixed with a large quantity of water, and briskly stirred so as to diffuse it pretty equally through the fluid, which retains the finer particles suspended for a short space of time, and

permits the coarser to settle to the bottom. The liquor thus impregnated is poured off from the sediment; and by allowing it to remain at rest for a sufficient length of time, it deposits the fine powder, from which the clear water is separated, either by carefully decanting it; or, if the sediment be very light, so as to be easily disturbed, by means of the glass syphon, pl. i. fig. 12. the longer limb of which being plunged into the vessel containing the fluid till it nearly touches the subsided powder, and the air sucked from it by means of the arm *h*, the whole of the supernatant fluid is drawn off, and the powder left in a fit state to be dried. The coarser particles first separated may be again levigated, and the elutriation repeated. Chalk and some metallic matters are thus prepared; and the process may likewise be employed for separating substances of different degrees of specific gravity, although of the same degree of fineness.

3. *Filtration* is intended for separating fluids from solid bodies partially suspended in them. Filters may be regarded as kinds of sieves; and are generally made either of very fine and close flannel, or linen, or of unsized paper formed into a conical shape, through which the liquid percolates clear, while the solid is collected at the apex of the cone, which is inverted. When the quantity of materials is large, and the solid is not in the state of very fine powder, nor very perfectly suspended in water, flannel or linen bags are to be preferred, as performing the process more quickly than paper. These are generally made in a conical shape, with the mouth stretched on a hoop or frame supported upon a wooden stand. When the solid residue is the part to be preserved, flannel filters may be used; but when the filtered liquor is the valuable product, linen is preferable, as it absorbs less of the fluid, which is also obtained in a more limpid state. The cloth must be well cleaned after each time it is used, to prevent any thing from remaining to injure subsequent operations. For smaller processes, unsized paper is the best material for forming filters. A square piece of this paper of a size proportionate to the quantity of the substance to be filtered is taken, and first doubled from corner to corner into a triangle, which by second doubling forms again a smaller triangle; and this when opened constitutes a paper cone, which is to be supported in a glass funnel, pl. i. fig. 11. before the liquor is poured into it.

Funnels are made of tin, or Wedgewood's ware, or glass, but the two latter only should be used in the laboratory. Those which are ribbed are preferable, as the paper adheres so closely to the sides of smooth funnels as nearly to prevent the filtration from proceeding, unless pieces of straw or thin glass rods be arranged round the inside, so as to form an unequal surface for the paper to rest upon.

In most instances the first portions of fluid that pass through a filter are turbid, and require to be poured back again into the filter, sometimes repeatedly until the pores are sufficiently obstructed to pass the most limpid part only of the liquor. In cases where the solid residue is small, and it is requisite to collect the whole of it, it is useful to have a small glass tube, drawn out to a fine capillary point at one extremity; by filling which with distilled water, and putting the larger end into the mouth, the force of the breath can direct a small strong stream of water round the sides of the paper in the funnel, which will wash down to its bottom all the minute particles of solid matter lodged on its sides.

The concentrated acids and alkaline solutions act too powerfully on the ordinary materials employed for filters, to be filtered in the common way; and therefore, when it is required that they should be filtered, which is not often the case, they are passed through strata of siliceous matter arranged in a glass funnel, in the following manner. An irregularly shaped pebble is first dropped into the throat of the funnel; then a layer of pieces of quartz, or broken flint-glass, is placed over it; and lastly, a thick stratum of coarsely powdered glass, or of well washed white sand, covers the whole. The substance to be filtered is poured gently on the surface of the sand, and soon passes through it and the substrata, leaving the impurities behind.

Expression is employed for obtaining the juices of fresh vegetables, and the unctuous vegetable oils. The subject is first bruised or coarsely ground, then inclosed in a hair-cloth bag, and subjected to violent pressure between the plates of a screw press. The bags should be nearly filled; and the pressure should be gentle at first, and gradually increased.

Vegetables in general, intended to be expressed, should be perfectly fresh; and should be submitted to the press as soon as they are bruised, as the bruising disposes them more readily to ferment: but subacid fruits yield more juice, and of a finer quality, when the bruised fruit is allowed to stand for some days in an earthen or wooden vessel. It is necessary to peel oranges and lemons before pressing them, to prevent the essential oil which their rind contains from mixing with the juice; and to some vegetables, which are not very juicy, the addition of a little water is requisite.

For expressing the unctuous seeds, in order to obtain the oil they contain, iron plates are employed; and the bruised seeds should be previously exposed in a bag to the steam of boiling water.

Despumation is employed to clarify fluids which are so thick and clammy as not to be able to penetrate through the substances of which filters are made, without some previous preparation. For this purpose it is sometimes required only to heat the liquor, which then throws up a scum that is to be carefully removed; but more frequently it is necessary to clarify it with the white of egg. When the substance is not spirituous, as syrups, for example, the albumen which is mixed with the fluid coagulates when it is boiled, and, entangling the impurities of the fluid, rises with them to its surface in the form of scum; but spirituous liquors may be clarified with isinglass without the assistance of heat, the alcohol coagulating the isinglass, which forms a scum, and descending to the bottom of the vessel, as in the former instance, carries with it all the impurities. Some expressed juices are clarified by the simple addition of any vegetable acid.

Besides the above methods of mechanically separating the parts of substances from each other, fluids of different specific gravities, mixed together, are separated by means of the separatory funnel, fig. 14. pl. i. It is chiefly used for separating the essential oils from the water they are entangled with during their distillation. The funnel is first stopped at the bottom, and then filled with the mixed fluids, the heaviest of which gradually subsides into the narrow part below; and when the cork at the bottom is taken out, and the stopper above a little loosened, it flows out; by which means the lighter is easily obtained in a separate state. Some of the essential oils are heavier, others lighter than water, but both can be thus separated with equal facility.

II. CHEMICAL OPERATIONS.

The operations of Pharmacy, which are strictly chemical, may be arranged in three classes.

a. Operations which produce chemical changes in bodies, separating the constituents, without any obvious decomposition.

b. Operations in which changes are produced by the chemical action of one set of bodies upon another, or attended with obvious decomposition.

c. Operations in which the oxygenizement and the disoxygenizement of bodies are effected by means of a very high temperature.

The changes produced by the operations arranged under the first class are effected,

1. By caloric - - - - -	Liquefaction.
	Fusion.
	Evaporation.
	Exsiccation.
	Distillation.
	Rectification.
	Dephlegmation.
	Sublimation.
2. By water - - - - -	Solution.
	Lixiviation.
	Maceration.
	Digestion.
	Infusion.
	Decoction.
	Extraction.
3. By other chemical agents	Coagulation.

1. *Liquefaction* is that operation by which certain bodies when exposed to a moderate heat melt, or are rendered fluid, after passing through several intermediate states of softness. Fat, lard, wax, resin, and many other similar bodies undergo liquefaction; which is therefore employed to facilitate the combination of these bodies in the formation of ointments. The vessels usually employed in the process of liquefaction are earthenware pans.

Fusion differs from liquefaction, in the sudden change from the solid to the fluid state which those bodies that are liable to it suffer on exposure to heat. There are no intermediate states of softness, but the fusible body, when heated to a certain point, immediately assumes the fluid form. This point differs very considerably in different solids; but in general simple substances are less fusible than compounds; and some of the simple earths cannot be fused without the addition of some other substances to promote their fusion. These are generally saline bodies, and are denominated *fluxes*.

Fusion may take place without changing the nature of the fused matter; but in general this operation is intended as a mean of promoting chemical action and of decomposing bodies. It is, however, generally confined to the metals, which are extracted from their ores; and afterwards moulded and alloyed by it. It is a species of operation seldom employed in pharmaceutical processes.

Fusion is usually performed in crucibles, the best of which are made of very pure clay, or potter's earth. Those formed of common clay with calcareous or siliceous earth are very fusible. The Hessian crucibles are composed of clay and sand, and when good, stand the fire very well; as do also Wedgewood's crucibles: but they are apt to crack when suddenly heated or cooled, — a circumstance, however, which may be remedied by using a double crucible, and filling the interstice with sand, or by coating the crucible with a paste of clay and sand. Crucibles formed of black lead resist very sudden changes of temperature; but they are destroyed if nitre be melted in them, and even a current of air acting upon them, whilst they are hot, destroys them. Crucibles are made of various forms, three-cornered or round, and fitted with covers, as represented pl. ii. fig. 4, 5. The lids may be luted on if necessary, with a mixture of clay and borax. Those crucibles, which are of a uniform thickness, have a reddish-brown colour, without black spots, and which have a clear sound when struck, are to be preferred.

In order to expose the lower part of a crucible to the utmost intensity of heat, and to prevent it from cracking by the draught of cold air which would be directed upon it, were it to be placed directly upon the grate of the furnace, it is usually raised upon a small stand, either solid or hollow, an inch above it, which, according to Dr. Kennedy, is the hottest part of the furnace.

Crucibles are also made of cast-iron, of fine silver, and of platina. The first, however, are destroyed when saline substances are melted in them, and when made red-hot in a current of air are apt to suffer oxidation: but in other respects they are durable, and can sustain sudden alternations of heat and cold without cracking. Some of the metallic crucibles combine many of the best qualities necessary for this set of instruments; particularly those of platina, which, however, are too expensive for ordinary use.

Evaporation is the dissipation of a liquid by means of heat, and is employed in pharmacy generally with the view of obtaining in a separate state any fixed substance which may be combined with water, or some other evaporable fluid. Thus, by exposing an aqueous solution of a salt to a certain degree of heat, the caloric which combines with the water renders it volatile, and disperses it in the form of an elastic aëriform fluid, while the particles of the salt being brought nearer to each other, and within the sphere of their mutual attraction, reunite, and the salt is obtained in its concrete state. This process differs from spontaneous evaporation, in which air is the principal agent, the liquid being diminished in quantity and dissipated in that fluid, independent of the action of caloric; whereas evaporation is not carried on by the air, nor even much accelerated by the exposure of a large surface, but only in proportion to the quantity of caloric which combines with the fluid, or the degree of heat at which the process is conducted. As the fluid which is dissipated is entirely lost, and sacrificed for the sake of the fixed substance with which it was combined, evaporation is only employed where the liquid is of little value, such as water; but where a solid is to be recovered from a more valuable liquid, as alcohol, for instance, the process of distillation is employed.

For small processes, very good evaporating dishes are made of the bottoms of broken retorts and matrasses, which may be cut smooth round the edges by means of a hot iron or ring, pl. iii. fig. 8. and thus converted into semiglobular[1] basins. The best evaporating dishes, however, are those of biscuit porcelain made by Wedgewood, and sold in assortments, the largest of which is capable of holding eight or ten pints. They are flat-bottomed, shallow vessels, with a lip in the upper edge, fig. 1. pl. iii. glazed in the inside; and thin, but of a dense hard texture. They will bear to be heated to the boiling point over a clear hot fire; but are apt to crack when a flame is allowed to play on them, or when the liquor is boiled to dryness, at the moment the last drop of fluid is expelled, unless the fire be much lowered.

It is preferable, however, when glass or earthenware vessels are employed, to apply the heat by the medium of sand; or, if a still more moderate heat be necessary, by means of boiling water, over which the evaporating dish is placed. The first is denominated a *sand-bath*; the second, a *water-bath*: but for processes on a large scale, shallow iron pots or leaden troughs are used, to which the fire is directly applied.

Exsiccation is a variety of evaporation, producing the expulsion of moisture from solid bodies by means of heat. It is generally employed for depriving salts of their water of crystallization. They are exposed to the action of a fire in an iron ladle or pot, or in a glass vessel; and after dissolving as they are heated, in the water they contain, or undergoing what is called the *watery fusion*, the water boils, and, evaporating, leaves the salt in the form of a dry mass. When the substances to be exsiccated are liable to decomposition in a temperature above 212°, as is the case with some of the compound oxides, the process must be conducted by the heat of a water-bath.

Distillation differs from evaporation only in the circumstance, that the vapour or volatile matter elevated is condensed in close

[1] The iron ring for this purpose has a wooden handle. It is made red-hot in the fire, then put upon the matrass which is to be cut; and, when the glass is sufficiently heated, by throwing on it a little cold water, it will generally break exactly at the circle heated by the iron ring.

vessels, and preserved. The mode of conducting the operation and the regulation of the heat differs according to the nature of the subsances operated on.

The simplest distilling apparatus, for smaller processes, is the retort and the receiver. The former consists of a nearly globular body, with a long, gradually tapering neck, which is bent nearly at a right angle with the body. This is the simplest kind of retort, fig. 3. pl. iv. and if the materials to be distilled be liquid, they should be poured into the body of the vessel by means of a very long funnel, which, by reaching completely into it, prevents any thing from trickling down the sides of the neck. In withdrawing it, it is necessary to keep it applied to the upper part of the retort, that the drop hanging from it may not touch the inside of the neck: for nicer purposes the tubulated retort is to be preferred, fig. 9. pl. iv. The bottom of either kind should be very thin, and of a uniform degree of thickness, so as to bear the sudden application of heat from an Argand lamp, or even from a naked fire. The receiver, fig. 9. pl. iv. *c*. should be larger than the retort, and of a globular form, so as to allow of a large surface for cooling the condensing vapour: and it may be either joined directly to the retort, by the neck of the latter passing into it, or by the intervention of a third piece, denominated an adopter; and in either case the joinings are usually protected by lutes. When the substance to be condensed is of a very volatile nature, as ether, for instance, the receiver must be artificially cooled below the temperature of the atmosphere, either by surrounding it with ice, or allowing water to trickle slowly over it, brought down from a trough placed above the receiver, by means of worsted threads: the constant evaporation which the water suffers on the surface of the receiver keeps it at the requisite degree of temperature for condensing the ether. Like the retort, the receiver may be also tubulated.

Sometimes, instead of the retort and receiver, the stoneware cucurbit, with its capital, fig. 10. pl. iv. or the glass alembic and capital, in one piece, are used. It is necessary, occasionally, to coat the retort, and the latter-mentioned vessels, with sand and clay, to enable them to sustain a high temperature, and the sudden alternations of heat and cold to which they are liable in common operations. By these kinds of apparatus, acids, and other substances which arise from chemical decompositions aided by heat, are distilled; and the process is named distillation *per latus*: but if the products be highly volatile, or of a gaseous nature, the pneumato-chemical apparatus, to be afterwards described, is required.

For the preparation of alcohol, and of distilled waters, the common still, fig. 1. pl. ii. is employed. It consists of two parts, — the boiler, and the head or capital. The boiler, which is the part to which the fire is applied, and contains the materials, is generally of a cylindrical shape, and may be sunk into a furnace, or immersed in a water-bath when the temperature requires to be nicely regulated. The *head* or *capital* is a large hollow globe, the upper part of which is drawn out into a tapering pipe, bent to a curve or arch, and terminating in the serpentine, or worm. These parts are generally made of copper; but the *worm* is a long pewter pipe of a decreasing diameter, which winds in a spiral direction obliquely through a deep tub filled with cold water. The body, head, and worm require to be luted together; but in general slips of paper dipped in flour paste, or pieces of wet bladder, are sufficient for this purpose. In this apparatus, the vapours are raised into the head, and thence pass into the worm, in which they are condensed, and issue in drops from the lower end of the pipe. By degrees the water in the refrigeratory becomes warm, and requires to be renewed: and hence the necessity of the tub being furnished with a stop-cock, by which the heated water may be drawn off without disturbing the apparatus. As in this species of distillation the vapour ascends before it is condensed, it is named distillation *per ascensum*.

In some cases, as in the distillation of some essential oils, the vapour instead of passing laterally, or ascending, is forced to descend. To produce this effect, a plate of tinned iron is fixed within any convenient vessel, so as to leave a space beneath it; and the materials to be distilled being laid upon this, they are covered by another plate accurately fitted to the sides of the vessel, and strong enough to support the fuel which is burnt upon it. By this means, the volatilized matter of the materials under the fire is forced into the lower cavity of the vessel, and there condensed. This mode of distilling is denominated distillation *per descensum*.

In many processes, a large proportion of the vapour which is extricated is incondensable; and unless there were some means by which these could escape, the apparatus would be burst in pieces. To prevent accidents, therefore, a small hole was generally left, either in the joinings of the vessels, or in the receiver, which could be kept shut, and occasionally opened when the quantity of confined vapour was supposed to be such as might endanger the rupture of the vessels. By this contrivance, however, much condensable vapour escaped, and a large proportion of the products of the distillation was necessarily lost. This defect of the old apparatus was firt attempted to be remedied by Glauber, whose hints were improved by

Woulfe, the inventor of the apparatus now commonly employed. It consists of a retort, generally tubulated, in which the materials are heated; a receiver, to detain any part of the product which is condensable by cold; and a bent tube, proceeding from the receiver to the bottom of a bottle; with two apertures, and about half full of water. Several bottles, however, are generally employed; and these, being placed side by side, are connected with each other by means of bent tubes, one limb of each proceeding from the top of the bottle immediately preceding, and the other plunging to the bottom of the liquid of the bottle next in order. The joinings of the apparatus are all made air-tight, except the opening of the last bottle furthest from the retort, so that any vapour which escapes must have passed through the liquid in the whole series of bottles, and left all its condensable matter before it can escape. One inconvenience, however, attends this apparatus when it contains no other parts than the above; which is, that after the distillation, as the retort cools, a vacuum is produced in it and the first receiver, which induces a suction or absorption from the other receivers through the bent tubes, and a retrograde motion of the liquid contained in them takes place through the whole apparatus; so that the products are mixed,—unless the operator is on the watch, to separate the retort and receiver, the moment the liquor begins to rise in the bent tube between the receiver and the first bottle. The best contrivance for remedying this defect is the tube of safety, invented by *Welter*, and represented in plate v. fig. 1. It is a bent tube with a bulb blown in that part of it which lies between the upper and lower flexure; and a small funnel at the top. This tube is sometimes used as a stopper to the tubulure of the retort, or to a separate opening in the receiver; or, as is represented in the plate, it is cemented into the tube passing from the receiver to the first bottle. When it is to be used, a little mercury is dropped into the funnel, so as to occupy the space of the tube which lies between the two lower flexures. The mercury excludes the external air during the distillation; but as soon as the vacuum is formed by the cooling of the vessels, the mercury is forced by the pressure of the atmosphere into the bulb; and not being in sufficient quantity to fill it, the external air passes by it in the bulb, and rushes into the apparatus; by which means the vacuum is filled up, and the absorption of the liquid prevented.

In chemical operations, when the gases which are separated during any process are to be preserved, the pneumatic trough, fig. 1. pl. v. is attached to Woulfe's apparatus. The construction of the trough differs according to the nature of the fluid with which it is to be filled. If water be employed, the trough may be made of stone ware, or of tinned iron well japanned, and of an oblong or a circular shape. It may be about 18 inches long, 14 broad, and 8 inches deep; with a shelf of the same materials, which should extend entirely across the trough, and have two small holes in it to convey the gas into inverted jars set upon it; and two larger holes to receive two bottle supporters. This trough should be nearly filled with water, and the jars intended to hold the gas should be also filled with the same liquid, and inverted; so that when placed upon the shelf, the water in the trough may ascend about half an inch up their sides, which enables them to retain either water or gas. If mercury be employed, which is essential when the gases to be extricated are absorbable by water, the trough may be made of some hard wood, as mahogany, or of marble. It is not required to be so large as the trough for water, and one part only need be sunk: the shelf should be on each side of this part which is called the well; and it is useful to have an iron or brass stem supporting a semicircular clip fastened into the substance of the trough, to support the jar when it is filled with mercury and inverted. By this apparatus any gases given out during distillation may be collected and preserved; but this is a circumstance in pharmaceutical operations which is attended to more with the view of guarding the operator against the effect of noxious gases, than of preserving gases for examination.

Rectification is the repeated distillation of any product obtained by distillation, when it is not perfectly pure. This second operation is carried on at a lower temperature, so that the more volatile parts only are raised, and pass over into the receiver, leaving the impurities behind. When the fluid is simply rendered stronger, as in the case of alcohol, by bringing over the spirit, and leaving behind the superfluous water, the operation is named *dephlegmation* or *concentration*. When the liquid is distilled off from any substance, the process is called *abstraction*; and *cohobation*, if the product be redistilled from the same materials, or from a fresh parcel of the same materials.

Sublimation is a species of distillation, in which the product of the volatilization is condensed in a solid form; but as this condensation takes place at a higher temperature than that of watery vapour, a much more simple apparatus is required. The process is conducted sometimes in a crucible, with a cone of paper or another crucible inverted over it, in which the product is condensed; and as in this case it is light and spongy, it was formerly denominated *flowers*. For other matters which are less volatile a cucurbit and capital, or a flask, or phial, are employed, and sunk about two-thirds in a sand-bath. The product in these cases is generally solid, and is denominated a *sublimate*.

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2. Of the operations by which chemical changes are produced in the forms of bodies by the action of water.

When a solid body is thrown into a liquid and disappears, the transparency of the liquid remaining the same, the process is named *solution*; or *solution* is that operation by which the aggregation of a solid is overcome by a liquid, and a compound produced which retains the fluid form, is transparent, and perfectly homogeneous. The liquid is generally supposed to be the substance exerting the active power, and has therefore been called the *solvent* or *menstruum*: it separates the particles of the solid or *solvend* from each other, and permanently suspends them by the state of combination into which they enter; but the attraction, as was before stated, is reciprocal, both as it regards the solid and the fluid. In general, the solution of every solid in a liquid can be effected in a certain quantity only, or is limited; and when it is carried to its ultimate point, the liquid is said to be saturated. The solvent power, however, is not always limited; there being some instances in which a solid dissolves in a liquid in any proportion: thus gum and sugar dissolve in water in every proportion. The solvent power of a fluid diminishes as it approaches to saturation, and the solution consequently goes on more slowly; but by raising the temperature, it proceeds again more rapidly, and a much larger portion of the solid is taken up than could have been dissolved at a lower temperature. This effect of temperature, however, does not take place in every instance; muriate of soda, for example, and some other salts, being dissolved in nearly as great quantity by cold as by hot water. When an increase of temperature increases the solubility of bodies, a portion of the solid, taken up by a heated liquid, is retained in combination as long as the increased temperature exists, but separates again as the solution is cooled down to the temperature of the atmosphere, or lower; and when this is properly conducted, salts are obtained in regular forms, or crystallization takes place.

Although a liquid be saturated with one solid, yet it may be still capable of dissolving a portion of another, and even of a third when saturated with the second; until it be combined with, or hold in solution, three, four, or five different bodies at the same time. The liquid, indeed, in this case does not dissolve so large a portion of any of the substances; but sometimes, from the mutual affinities which the substances exert, the whole proportion of solid matter dissolved is very much increased.

The solution of saline bodies in water requires no particular apparatus; as it can be conducted equally well in phials, or jars, or basins, provided the materials of which they are composed be such as can resist the action of the solvend.

Lixiviation is a term applied to solution when the saline body consists of both soluble and insoluble ingredients. On a great scale it is generally performed in large tubs, or vats, having a hole near the bottom containing a wooden spigot and faucet. A layer of straw is placed at the bottom of the tub, over which the substance is spread, and covered by a cloth; after which hot or cold water, according as the salt is more or less soluble, is poured on. The water, which soon takes up some of the soluble parts of the saline body, is after a little while drawn off by the spigot; and a fresh portion is successively added and drawn off until the whole of the soluble matter be dissolved. The straw in this operation acts as a filter; and the cloth prevents the water from making a hollow in the ingredients when it is poured on, by which it might escape without acting on the whole of the ingredients.

In smaller operations lixiviation may be conducted in glass matrasses, and the *ley*, which is the name given to the impregnated liquor, filtered through paper in a glass funnel.

Maceration is that operation by which the soluble parts of substances, chiefly of a vegetable nature, are obtained in solution by keeping them immersed in cold water for a sufficient length of time. It is frequently employed as a preparation for infusion and decoction, which are always rendered more effective by the previous maceration of the materials.

Digestion is an operation similar to maceration, but the power of the fluid is aided by a gentle degree of heat. It is usually performed in a glass matrass, and the evaporation of the liquid impeded by stopping the mouth of the matrass slightly, with a plug of tow, or tying over it a piece of wet bladder perforated with small holes. When the menstruum is valuable, as alcohol, for instance, another matrass, with a smaller mouth, may be inverted over the former, and the joinings secured by a piece of wet bladder; or, what is perhaps preferable, a long open glass tube may be luted to the mouth of the matrass containing the materials. By these means, any part of the liquor which is resolved into steam by the heat, is condensed, and conveyed back upon the materials. The matrass may be heated either by a common fire, a water-bath, or a sand-bath; and when either of the latter are used, it should not be sunk deeper in the water, or the sand, than the portion that is filled. The process has been denominated *circulation*, when the condensed vapours are returned upon the ingredients.

Infusion is intended principally to extract the volatile and aromatic principles of vegetable substances, which would be dissipated by digestion or decoction; and also those parts of vegetables which are more readily soluble in water, as gum, sugar, extract, tannin, the salts, and part of the resin, from the insoluble parts. The water is poured boiling hot on the materials, sliced, or reduced to a coarse powder, and kept in a closely covered vessel until they are cold; when the infusion or liquor is decanted off for use. The best infusion-pots are of a globular form in the body, with the neck cylindrical, and having a very large lip or spout furnished with a grate, which should incline inwards towards the top, so as to retain the ingredients in decanting off the infusion. Infusions differ according to the length of time the water has stood on the materials, and the heat used. In some instances agitation is necessary. Infusions may be made in the cold; and these are in general more grateful, although weaker.

Decoction, or boiling, is intended to answer the same purposes as infusion; but in a more extended degree. The solvent power of the menstruum is increased by the degree of heat: hence the liquor is deeper coloured, and more loaded with the soluble principles of the vegetable. It is employed with advantage to extract the mucilaginous parts of plants, their bitterness, and several other of the vegetable principles. It is generally performed in slightly covered vessels; but when the menstruum is valuable, as alcohol for instance, the common still is used, in the body of which the decoction is prepared, while the vapours that would otherwise escape are condensed and preserved.

Decoction, however, is often a prejudicial mode of preparation, particularly for those vegetables the virtues of which depend wholly or in part on the essential oil, or other volatile principles they contain; and even some fixed principles, such as extractive, are injured by it. Thus, cinchona bark is rendered nearly inert by long decoction, particularly if atmospheric air be freely admitted; for in these instances the extractive is oxygenized, and becomes insoluble.

Extraction is the result of either infusion or decoction: if the liquor obtained by either of those processes be subjected to evaporation, the watery part is dissipated, and the part extracted by them is obtained in the solid form, and denominated an *extract*. The same objections may be urged against this species of preparation as were stated under *Decoction*.

All the forms of preparation in which water is the agent may be regarded as various modifications of solution. When alcohol or diluted spirits are employed as menstrua, the ingredients subjected to their action are generally macerated, and the filtered fluid, which is the product, is denominated a *tincture*.

3. *Changes produced by chemical agents.*

Under this division we have only to notice *Coagulation*, which is the conversion of a fluid into a solid more or less consistent. The means employed for this purpose are increase of temperature, or the addition of acids and runnets. The effect appears to arise from a new arrangement of particles produced by the affinity exerted between the solid particles contained in the fluid, and the coagulating substance.

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b. *Of the* OPERATIONS *in which changes are produced by the chemical action of one set of bodies upon each other.*

Decomposition, which is the separation of bodies that were chemically combined, is produced in some cases by heat, or the introduction of caloric into a body in sufficient quantity to separate the particles from each other to a distance beyond the sphere of the attraction of affinity which held them in combination; but in the greater number of instances it is the result of a superior affinity, which, unless modified by bulk and other circumstances, breaks the weaker affinity that holds the principles of the substance about to be decomposed in union, and produces new compounds.

In pharmaceutical operations decomposition frequently occurs; and it is of the utmost importance, in extemporaneous prescription, to be acquainted with the circumstances which occasion it.

Dissolution is the appellation given to cases of solution accompanied with decomposition, or some alteration in the nature of the dissolved body. In general, the dissolution of a body is attended with considerable effervescence, owing to the extrication of gases; and therefore the operation requires to be performed in capacious vessels, to prevent the loss of the materials.

Precipitation is an operation also in which decomposition takes place, a solid substance being thrown down from a liquid in which it was held in solution, by the chemical action of another body which is added to it. The substance employed to produce the precipitation is denominated the *precipitant*; the substance which is separated by its action, the *precipitate*. Thus, if into a solution of sulphate of magnesia a solution of soda be dropped, the magnesia separates from the sulphuric acid, falls to the bottom, and forms the precipitate; while the alkali, which is the precipitant, combining with the acid, thus set free, remains in solution in the state of sulphate of soda. Sometimes, the precipitate is separated by the precipitant having a greater affinity for the liquid, and thence weakening its attraction to the substance which it held in solution. Alcohol, for example, when added to a saturated solution of sulphate of magnesia, precipitates the salt in a crystallized form, and combines with the separated water. At other times the precipitate is an insoluble compound formed by the union of the added substance with that which was previously held in solution; as, when a solution of barytes is added to a solution of sulphuric acid, sulphate of barytes is formed and precipitated. The mixture of a solution of a compound salt with the solution of another compound salt may produce a precipitate which is an insoluble compound, while a new soluble compound is formed at the same time and remains in solution; in which case the decomposition is produced by double elective attraction: thus, if a solution of superacetate of lead be added to a solution of sulphate of zinc, the oxide of lead leaves the acetic acid, and combining with the sulphuric, forms sulphate of lead, which is insoluble and falls to the bottom; while acetate of zinc, formed by the union of the oxide of zinc with the acetic acid, remains in solution.

When the precipitate is the chief object of the process, it is necessary to wash it after it is separated by filtration. This operation requires little attention when the substance thrown down is insoluble in water; but when it is in some degree soluble, attention is required to prevent the loss which might result from the use of too much water.

The best precipitating vessel is a very tall glass jar narrower at the bottom than at the mouth, so that the precipitate may readily collect by subsidence, and the supernatant liquor be decanted off with more ease, fig. 7. pl. iii.

Precipitation is intended to separate solids from solutions in which they are contained; to produce new combinations, which cannot readily be formed by the direct union of their constituents; and to purify solutions from precipitable impurities. A knowledge of those substances which produce precipitation is also of much importance, in extemporaneous prescription; to prevent the virtues of remedies from being destroyed by improper combinations. The following Tables of Precipitants are extracted from those drawn up by Dr. Thomson.[1]

	PRECIPITANTS.
1. ALKALIES.	
Potash - - - -	Tartaric acid, supertartrates.
Soda - - - - -	0.
Ammonia - - -	Fixed alkalies.[2]
2. ALKALINE EARTHS.	
Barytes - - - -	Sulphuric acid, sulphates.
Lime - - - - -	Oxalic acid, oxalates.
Magnesia - - -	Phosphoric acid, phosphate of soda.[3]
3. EARTHS PROPER.	
Alumina - - - -	Ammonia, hydrosulphuret of potash.
4. METALLIC OXIDES.	
Silver - - - -	*Muriate of soda.*
Mercury - - -	Muriate of soda.
Copper - - - -	Iron.
Iron - - - - -	Succinate of soda, benzoate of soda.
Lead - - - - -	Sulphate of soda.
Zinc - - - - -	0, alkaline carbonates?
Antimony - - -	Water, hydrosulphuret of potash.
Arsenic - - - -	Nitrate of lead.
5. ACIDS.	
Sulphuric - - -	Muriate of barytes.
Carbonic - - -	Muriate of an alkaline earth.
Boracic - - - -	Sulphuric acid.
Nitric - - - - -	0.
Acetic - - - - -	0.
Benzoic - - - -	Muriatic acid.
Succinic - - - -	Sulphate of iron.
Oxalic - - - -	Muriate of lime.
Tartaric - - - -	Potash.
Citric - - - -	Acetate of lime.

In some cases, when decomposition is effected by the addition of another substance, the separated body is not precipitated, but rises to the surface, and is thence denominated a *cream:* thus, by the addition of any acid to a solution of soap, the alkali unites with the acid, while the oil is separated, and swims on the surface of the liquor.

Crystallization, although it can scarcely be regarded as a

[1] *System of Chemistry*, 4th edit. iii. 664—671.

[2] In strict language, no precipitation takes place, but the fixed alkalies added to solutions containing ammonia render it perceptible by its odour.

[3] The precipitation of magnesia in this case is not direct; but to effect it a solution of carbonate of ammonia must first be added to the solution of magnesia; no precipitate will appear, but on adding phosphate of soda it falls down in an insoluble state, in combination with the phosphoric acid. Dr. Wollaston suggested this method.

species of precipitation, yet is very nearly allied to it. We have already noticed the theory of the operation, and therefore it only remains to mention in this place the modes in which it is effected for pharmaceutical purposes.

For the crystallization of any substance, it is necessary that it should be in a state of fluidity, either by the agency of caloric or that of water.

Metals and other bodies, which are capable of being fused, crystallize if they be allowed to cool very slowly, and are left at the same time in a state of rest: but this species of crystallization is never required for pharmaceutical purposes.

Salts are obtained in a crystalline form by a proper management of their watery solutions. When the salt to be crystallized is considerably more soluble in hot than in cold water, it is only necessary to saturate hot water with the salt, and set it aside to cool; but this must be slowly effected, by covering the vessel with a cloth to prevent the access of cold air, and the too rapid consequent formation of a pellicle, which would produce an irregular mass, instead of well formed distinct crystals. Crystals thus formed generally contain a considerable proportion of water of crystallization. When the salt is not more soluble in hot than in cold water, crystals are obtained by evaporating the solution while hot, until a pellicle forms on its surface, when it is set aside to cool, during which the crystals form; and after they are separated the evaporation is repeated, and another crop obtained, till by a succession of evaporations the greater part of the salt contained in the solution is separated in the crystalline state.

The following method of obtaining very large and regular crystals has been pointed out by M. Leblanc.[1] The solution is first evaporated to such a consistency that it shall crystallize on cooling: when it is cold, the liquor is poured off from the mass of crystals which generally form at the bottom, and is put into a flat-bottomed vessel. In this, solitary crystals gradually form, the largest of which are to be picked out and placed in another flat-bottomed vessel at some distance from each other, and a quantity of liquid, obtained in the same way by evaporating a solution of the salt till it crystallizes on cooling, poured over them. The position of each crystal is now to be altered once a-day by means of a glass rod; for, when not turned, the face on which the crystal rests receives no increase of size. When they have gained considerably in magnitude the most regular are to be selected, and each of them put separately into a vessel filled with the same liquid,

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[1] *Journal de Physique*, lv. 300.

and turned as already described several times a day, until they attain the largest size which the species of crystal under treatment is capable of acquiring. It is, however, necessary to observe, that if the crystals be allowed to remain too long in one portion of the solution, the quantity of salt it contains becomes so much diminished, that the liquid re-acts upon the crystal, and partially dissolves it.

If a crystallizable salt be perfectly pure, the whole of its solution may be crystallized; but if two or more salts exist in the same solution, after crystals have been obtained by several successive evaporations and coolings, the remaining portion of the fluid, although saturated with saline matter, yet refuses to crystallize, and is then denominated *mother water*.

The vessels best adapted for crystallization are large flat dishes of Wedgewood's ware, such as have been already described as proper for the evaporation of liquids. When the crystallization is to be conducted slowly in the heat of the atmosphere, with the free access of air, deeper vessels are required, that there may be a considerable body of liquid; by which means crystals of considerable size and very regular in figure are procured.

Crystallization is intended to obtain crystallizable substances in a pure state; and to separate them from each other by taking advantage of their different solubility at different temperatures.

FERMENTATIONS.

The constituents of vegetable matter, when separated from the living plant, and placed under certain circumstances, act upon each other, and a spontaneous decomposition takes place even at the ordinary temperature of the atmosphere. This process has been denominated *fermentation* by chemists, on account of the intestine motion with which it is accompanied: and as its phænomena and results vary according to the nature of the vegetable matter subjected to it, and the circumstances under which it occurs, the general process is divided into three species easily distinguished from each other. The 1st is named the *vinous fermentation* — of which the products are wine, beer, and other vinous fluids: the 2d, the *acetous fermentation*, which produces acetic acid or vinegar: and the 3d, the *putrefactive fermentation*, in which gases chiefly are produced, and ammonia.

Each of these is occasionally artificially produced for pharmaceutical purposes, and therefore requires to be described.

Vinous fermentation. All vegetable substances containing saccharine matter, and a peculiar glutinous principle analogous to the gluten of wheat, are susceptible of this fermentation. For its commencement, however, the presence of water, extract, and a small proportion of vegetable acid, with a certain increased temperature, is requisite. In juices in which these are present, the fermentation is spontaneous; but as *yeast* contains the peculiar gluten, and the other principles necessary for exciting the vinous fermentation in any sweet vegetable juice or decoction, it is frequently used for this purpose in the formation of beer and wines. Soon after yeast is added to these substances, or to *wort*[1], or to *must*[2], an intestine motion commences in the liquor, its temperature rises, it becomes turbid, and carbonic acid gas is extricated: but after some time the fermentation again gradually subsides, the scum which was formed during its continuance rises to the surface, or sinks to the bottom; the liquor becomes lighter, and instead of its sweet taste has acquired that peculiar taste and flavour which is denominated vinous. This process of fermentation is never employed in the laboratory for the preparation of vinous liquors, although these are articles of the materia medica: but the cataplasms, which are prepared from carrots and similar vegetables mixed with yeast, derive their virtues from the vinous fermentation into which they enter, extricating a large quantity of carbonic acid gas, which operates as a powerful antiseptic.

Acetous fermentation. All liquors prepared by the vinous fermentation are susceptible of the acetous when kept exposed to the air in a temperature between 70° and 90°. Under these circumstances the liquor gradually becomes thick, its temperature increases, and filaments are seen moving through it in every direction, an intestine motion being excited, accompanied with a hissing noise: but as this motion subsides, these filaments fall to the bottom or attach themselves to the sides of the vessel, the liquor becomes clear and transparent, and has acquired a very sharp acid taste, — in which state it is denominated vinegar, — and contains, besides the acetic acid and water, which are its principal components, mucus, malic acid, supertartrate of potash, and some other vegetable constituents.

Pure alcohol, even when diluted with water, is not susceptible of this fermentation, but it enters into it when united with other fermentable bodies: thence wine and vinous liquors, which contain, besides alcohol, sugar, and some mucilaginous

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[1] Wort is an aqueous infusion of malt. It consists of saccharine matter, starch, gluten, tannin, and mucilage.

[2] Must is the expressed juice of the grape. It contains water, sugar, a peculiar matter, which changes into gluten by contact with the air, mucilage, supertartrate of potash, tartrate of lime, muriate of soda, and sulphate of potash.

and extractive matter, are employed for making vinegar. In this process the alcohol is supposed to be decomposed, and oxygen absorbed; carbonic acid is formed, but is retained in the liquor; and it is probable, as Dr. Murray has suggested, that the ferment affords nitrogen, which it is now ascertained, enters into the composition of acetic acid.[1]

Many vegetable infusions and decoctions undergo this fermentation in warm weather; and hence the necessity of making these every day during summer, as by the decomposition which takes place, their medicinal virtues are completely destroyed.

Putrefactive fermentation. Almost every vegetable substance, when kept in a moist place, in a temperature not under 45° nor above 70°, undergoes spontaneous decomposition, its solid structure is completely destroyed, and its ultimate principles entering into new combinations, escape in the gaseous or aëriform state, leaving behind a small quantity of earthy and metallic matter only, which the vegetable body contained.

This process, which is denominated the *putrefactive fermentation*, does not absolutely require the contact of air, but water in every case appears to be essential. Vegetable bodies, which are very soluble in water, suffer it most readily; the surface of the liquor becomes covered with a mould; various elastic fluids, in which ammonia and phosphureted hydrogen gas are often perceptible, with other matters which produce a fœtid odour, are extricated, and it is ultimately completely decomposed.

The knowledge of the circumstances which promote this species of spontaneous decomposition points out the necessity of preserving vegetable substances in perfectly dry places; and when they have a tendency to attract moisture, the exposing them in a free current of air to dissipate the humidity which they would otherwise absorb.

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c. *Of the* OPERATIONS *in which oxidizement is effected by means of a high temperature.*

The degree of temperature at which these operations are conducted cannot generally be obtained from a common fire; and therefore, before describing the operations themselves, it is necessary to notice the nature of furnaces, which are instruments of the most universal use in pharmaceutical chemistry.

Furnaces differ in construction, according to the particular

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[1] *System of Chemistry*, iv. 465.

purposes for which they are chiefly intended; but the following essential parts are common to all furnaces. 1st, The body or fire-place for holding the fuel and the vessel containing the materials to be submitted to the action of heat. 2d, The chimney by which the heated air and the smoke escape. 3d, The ash-pit, into which the ashes fall, and through holes in the side of which fresh air is admitted to the burning fuel.

In a well-constructed furnace, the whole of the air which enters the ash-pit passes through the body of the furnace, and supports the combustion, after which the residue being highly rarefied passes off by the chimney; on the due height of which, and the proper regulation of the access of atmospheric air from below, the strength of the combustion and consequently the heat produced altogether depend. The access of the air is generally regulated by registers; which, in portable and smaller furnaces, are iron plates pierced with many holes of different sizes, which are generally fitted with brass stoppers, so that according to the number of holes opened, a greater or smaller quantity of air is admitted to the burning fuel. The chimney should be narrower than the body of the furnace, and of such a length that it can be heated throughout by the rarefied air which ascends through it; for it is by producing in the chimney a column of air of much less specific gravity than a corresponding column of the external air, that fresh air is constantly forced through the body of the furnace from below, and a strong draught produced. If the chimney be too short, all the advantage to be derived from the above circumstance is not obtained; and if on the other hand it be too long, the air loses its heat before it reaches the summit, and impedes to a certain extent the ascent of the rarefied air. According to Macquer, when the internal diameter of the furnace is 12 or 15 inches, and that of the chimney 8 or 9, its height should be 18 or 20 feet.

Of whatever substance furnaces are made, unless they be fixed and built of fire bricks, they should be coated to prevent the radiation, and consequent loss of heat; and the best composition for this purpose is clay and sand. It is perhaps better, however, first to put a coating of charcoal and clay next to the sides of the furnace, as was recommended by Dr. Black, particularly if it be made of plate-iron. The proportions he recommended were one part by weight of fine clay and three parts of charcoal; which being reduced to powder, and kneaded together with water, the mass is to be divided into balls of a moderate size; and these being applied to the sides of the furnace, are to be beat strongly with the face of a broad hammer, until a general coating of about one inch and a half covers the inside of the furnace, and the cavity assumes an elliptical form.

The most convenient portable furnace is that which was contrived by Dr. Black. It consists of an oval iron case, about 22 inches in height, 20 inches in diameter in the length of the oval, and 15 inches across; and lined in the body with the coating already described. On the top is fixed an iron plate perforated with apertures; one large, intended to receive a sand-bath, a still, or similar apparatus; and the other smaller, to which an iron tube, which acts as a chimney, is to be fixed. At the bottom of the body of the furnace, directly under the larger aperture, the grate is fixed; and under it the ash-pit receives the body, resting on a strong ring that encircles it, at about half an inch deep. The ash-pit is furnished with a door which opens on hinges, intended for removing the ashes; and also a register to regulate the admission of air to the burning fuel. The register is a plate of iron perforated with six apertures, the size of which increases in a geometrical ratio; so that by taking out the plugs with which they are stopped, either one or more at a time, the supply of air, and of course the heat to be excited, can be regulated with great nicety. The fuel is introduced at the top; but there is a door also, occasionally, in the side of the body of the furnace, through which fuel can be supplied during the conducting of any process; although, unless it be made to shut very close, this door is a disadvantage, as it prevents the admission of the air from being so precisely regulated. This furnace may be used for a great variety of operations, and may be fitted with a dome for the purpose of throwing down the flame when it is to be used for fusing metals.

For small operations, and when a great heat is not required, a furnace may be constructed by simply inverting a large black-lead or a Hessian crucible over another which is perforated at the lower part, and is fitted with a moveable grate for supporting the fuel; or a sufficient heat for a great variety of small operations may be obtained from a lamp, on the principle of Argand's, with a double concentric wick, and having rings attached to a brass rod on which they slide, for supporting the retort or matrass at any height above the flame.

With regard to *fuels*, the best are undoubtedly charcoal and coak, or a mixture of these. The advantages of *charcoal* are its kindling readily, burning with a strong clear heat in a small draught, without running into slag, choking the grate, or melting the walls of the furnace; and owing to its containing only matter which is extremely combustible, the flues or chimneys never collect soot or other foulnesses. The chief objection to charcoal is its great expense. *Coak* is much less expensive; but as it contains a mixture of earths and metallic oxides, it is apt in an intense heat to run together into a tough cohesive slag, which adheres to the walls of the furnace, and to the sides of crucibles, choking up the grate, and of course preventing the proper draught for carrying on the combustion. These disadvantages, however, are remedied by mixing it with an equal bulk of charcoal; and these united form the best fuel when an intense heat is required.

The pharmaceutical operations (usually performed in furnaces) are—

Fusion.
Evaporation.
Distillation.
Sublimation.
The oxidizement of metals.
The deoxidizement or reduction of metals.

The four first of these have been already described.

Oxidizement of metals. This term signifies that process by which metals are converted into oxides, by absorbing oxygen from the air, when exposed to a certain degree of heat. The disengagement of the caloric and light which oxygen gas contains, by the solidification of the oxygen in the oxide, is scarcely perceptible when the operation is conducted in atmospherical air; but if the oxidizement takes place in oxygen gas, it is rapidly effected, and caloric and light are very evidently extricated. This mode, however, of oxidizing metals is employed in small experiments only; but in all the processes of the laboratory for procuring oxides by the aid of heat, common air yields the oxygen. The metal, if it be not volatile at the temperature required for its oxidizement, is exposed to the heat of the furnace in a flat dish of baked clay called a *roasting test*, and frequently stirred to present fresh surfaces to the air: but, if the metal be easily volatilized, as is the case with zinc, it is thrown by pieces, at separate intervals, into a deep crucible, so placed as to admit the air and allow of the additions being made. If mercury be the metal operated on, it is generally put into a flat-bottomed matrass with a very tall narrow neck, the mouth of which is left open, and which is placed in a sand-bath, and kept at a degree of heat nearly equal to the boiling point of the mercury, for several days; but it is perhaps better to use a retort with the bottom flattened, and the neck only slightly bent, that the globules of mercurial vapour may be condensed, and the metal fall back into the vessel.[1] In this process the atmospheric air furnishes the oxygen, which readily combines with the volatilized mercury, while the form of the apparatus is intended to permit a renewal of it constantly to take place, without allowing the escape of the mercurial vapour.

Deoxidizement of metals, or their reduction, is that process in which the oxygen of a metallic oxide is separated, and the metal recovers its metallic form and properties. It is seldom performed on a large scale in pharmacy; but in cases of metallic oxides having been taken into the stomach, and proving fatal, it is of importance, in ascertaining their nature, to be able to reduce them to the metallic state by means of the blow-pipe and lamp; an apparatus by which minute substances may be almost instantaneously heated to a great degree, and their natures discovered with much accuracy.

The most common blow-pipe is a tube of brass or iron, bent near one of its extremities, and drawn out sufficiently fine to keep up a constant stream of air when it is blown into by the mouth applied to the opposite end. This form of blow-pipe is liable to one inconvenience, from the condensation of the moisture of the breath, in the course of blowing; to remedy which, a hollow ball or bulb is made near the small end of the pipe; and to render it more portable, this is divided through the middle, and fitted with a screw so as to be put together when used. Small separate jet pipes, or caps, are frequently adapted to slip on the small extremity of the blow-pipe, by which means any size of bore may be had recourse to, as a larger and more moderate, or a smaller and more intense flame is required. The flame for blowing through is best obtained from a wax or tallow candle with a very large wick, which must be kept moderately short by snuffing it frequently, and it must also be turned a little aside from the pipe.

In using this apparatus with advantage and ease, a little practice is necessary. As the flame is often required to be kept up for several minutes, the respiration must be carried on through the nostrils without interruption, and the stress of blowing performed merely by the compression of the cheeks upon the air held in the mouth. In subjecting any substance to experiment, it is to be placed either on a piece of charcoal, or in a platina spoon. When charcoal is employed, a large, compact well-burnt piece should be chosen, and a small shallow hole scooped in it for receiving the substance to be heated. The flame of the candle or lamp is then to be directed upon this by means of the blow-pipe. The charcoal soon kindles

[1] *Higgins's Minutes. Aikin's Dictionary*, ii. 75.

round the hole, which is gradually enlarged; and the heat being thereby augmented and kept up uniformly round the substance, the charcoal aids by its chemical effect the reduction of it if an oxide, or its deoxidizement if a fixed acid. Carbonate of lead thus treated is converted into a globule of metallic lead; and the phosphates are partially reduced to phosphurets.

In many operations, much inconvenience arises in using the common blow-pipe from both the hands of the operator being engaged; and therefore a double pair of bellows, which is fixed below the table, and worked by the foot of the artist, has been invented for giving the blast. Means have also been contrived for producing the blast by a stream of oxygen gas, or of mixed gases, as of oxygen and hydrogen, which excite a much more intense heat than can be produced by any other method.[1] A very ingenious blow-pipe is that of Mr. Paul of Geneva, in which the flame is produced by vapour of alcohol. See *fig.* 6. pl. iii.

COATINGS, CEMENTS, AND LUTES.

In many chemical operations, although the nature of the substances require that glass vessels be used, yet, from the degree of heat to which they are exposed, these must be protected on the outside by a coating; and in all operations where the products are in any degree volatile, it is of importance that the joinings of the parts of the apparatus should be perfectly secured: hence the necessity of coatings and lutes: and cements are requisite for repairing flaws and cracks.

Coatings are applied to the insides of furnaces to prevent the too quick dissipation of the heat, and also to protect the iron and materials of which the furnace is made from being destroyed by the action of the fire. The coating used by Doctor Black has been already described; but another nearly as good may be formed, by coarsely grinding fragments of pottery, and mixing the powder with moist clay in sufficient quantity to allow it to be moulded when wet. To render it more tenacious, some fibrous matter is generally added to the mixture, such as chopped cow-dung; the proportion of which, as recommended by Baumé, may be one ounce to every five ounces of the mixture. This is to be applied in the manner already described.

The same kind of coating may be used for glass vessels which

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[1] For descriptions of a blow-pipe invented by Mr. Newman, for this purpose, and improved by Dr. Clarke and others, see *Journ. of Science and the Arts*, vol. ii. p. 104. *Annals of Philosophy*, vol. viii. *passim*. *London Med. Repository*, vol. vi. p. 376. vol. vii. p. 21.

are to be exposed to a red heat. The following is the mode of applying it. After kneading the coating material, so as to render it very plastic, let it be spread out on a flat table, and lay the bottom of the retort in the middle of the mass; then turn up the edges of the cake, so as to bring it round the whole of the vessel, pressing it down in every part with the fingers till it applies uniformly and closely. The material may also be applied in the state of thick cream, by dipping the retort repeatedly into it; drying it after each immersion by turning it before the fire. The different layers of coating may be thus laid on very equally, from the thickness of $\frac{1}{4}$ to $\frac{1}{2}$ an inch; so as to make the retort like a strong earthen retort glazed in the inside; and as the coating agglutinates in a full red-heat, it will form an impenetrable covering which cannot be detached from the glass.

Cements and *Lutes* are formed of the same materials. They are generally composed of unctuous or resinous substances; mucilaginous or gelatinous substances; or of clay, lime, and similar materials capable of resisting a high degree of heat.

a. *Unctuous and resinous Lutes.* — These should be viscid, plastic, compact, and possess the power of resisting acrid vapours. The following are the best of this class.

1. Melt eight parts of bees-wax with one of turpentine, and according as it is required to be more or less consistent or pliable, add different proportions of any resinous substance. This lute adheres very closely to the glass, is not easily penetrated by acrid vapours, and is very manageable. It cannot bear a heat higher than 140°.[1]
2. Dissolve spermaceti, and when melted, while it is hot, throw into it bits of caoutchouc. This is an excellent lute where much heat is not required to be employed.
3. Take pure, dry, unbaked clay finely powdered, beat it for several hours with a heavy iron pestle in a brass mortar, dropping in slowly some boiled linseed oil; or, some amber varnish, prepared by melting yellow amber in an iron ladle, and mixing it with linseed oil. This lute can sustain a considerable degree of heat, is impenetrable by acids and spirituous liquors, and adheres very strongly to metallic or glass vessels previously rendered perfectly dry. As it softens in some degree, however, by heat, it is necessary to surround the luting with pieces of wet bladder, and to secure the whole by packthread firmly tied round both above and below the joint.[1] This lute improves by age. It should be kept in a covered pan in a cool cellar.
4. Glazier's putty, which is a composition of chalk and drying linseed oil, resembles very much the above lute in its qualities, and may be used as a substitute for it.

[1] Lavoisier.

5. Take four parts of common resin, one of yellow wax, and one part of fine brick-dust; melt the two former together, and when they are melted stir in the brick-dust. This lute adheres with great firmness, and forms also a good cement for stopping cracks in glass vessels.
6. Six parts of clay, one part of iron filings, and enough of linseed oil to form them into a paste, make a good cement for stopping cracks in iron vessels intended to be strongly heated.
7. The following cement is recommended for joining together glass or steel. "Take of mastich five or six bits as big as peas, and dissolve them in as much alcohol as will render them liquid. In another vessel dissolve as much isinglass (previously soaked in water) in brandy or rum as will make two fluid ounces of a strong glue; warm it, and incorporate with it by rubbing, two or three small bits of galbanum or ammoniacum, and the mastich solution. Preserve the mixture in a well-stopped bottle, and gently warm it before use."[1]

b. *Mucilaginous and gelatinous Lutes* are adapted only for operations which do not require a high temperature, and in which very acrid vapours are not extricated. They are easily applied, are sufficiently adhesive, and can be readily removed, by simply moistening them with water.

1. Under this head may be mentioned the simple application of moistened bladder. To render it very adhesive, it should be soaked in tepid water, until it feels clammy to the touch; after which it contracts considerably as it dries, and adheres with a sufficient degree of force.
2. Linseed meal kneaded up with water to a sufficient consistence, and applied pretty thick over the joinings of the vessels, or almond meal treated in the same manner, form very convenient lutes, which dry and become firm in a very short time.
3. Flour paste spread upon slips of moistened paper forms a sufficiently good lute for many purposes.
4. Smear slips of linen on both sides with white of egg, then apply these neatly to the joinings of the vessels, and when applied shake loosely over them some finely powdered quicklime. This lute dries very quickly, is extremely hard, very cohesive, impervious to water, and impenetrable by most kinds of vapours.
5. Mix powdered plaster of Paris with white of egg, milk, glue, starch, or any mucilage, and apply it immediately.
6. Mix together equal parts of clay and lime, with about one-third of flour and white of egg.

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[1] *Aikin's Dictionary of Chemistry.*

7. Mix together equal parts of colcothar and lime, with white of egg.

All the cements containing lime and gelatinous substances become so very hard that they cannot be separated from glass vessels without the aid of a sharp knife and some force; and, therefore, they can scarcely be applied to very thin vessels. They will not confine very corrosive acid vapours for a great length of time; but are excellent lutes for preserving a complicated apparatus steadily united and air-tight; and they will bear nearly a red heat. They are also the most useful kind of cement for applying to any accidental crack or failure of a lute already on, although a stream of vapour may be bursting through at the time.[1]

c. *Earthy Lutes* are intended for operations which require a high temperature. The following are the best of this class.

1. Mix burnt gypsum, in powder, with water to the consistence of a thick cream, and apply it immediately. This forms a lute which sets as soon as it is applied, and is firm; but a slight blow will easily crack it.
2. Dissolve one ounce of borax in half a pint of boiling water, and add as much slacked lime as will make a paste. By using a smaller portion of lime, this lute forms an excellent glazing for earthen-ware retorts, over which it should be spread with a brush; but when dry, a coating of slacked lime and linseed oil, beaten till the mixture is plastic, should be laid over the whole of the lute.
3. A very valuable fire lute may be made of about one part of glass of borax, five parts of brick-dust, and five parts clay, finely powdered together, and mixed with a little water when used.
4. The same composition which has been already described as a proper coating for the inside of furnaces, is also an excellent earthy lute.

If the beak of a retort be too small to fit accurately to the neck of a receiver, the vacancy should be filled up, by introducing short pieces of soft wood or of cork; and if the disproportion be very considerable, a cork must be fitted to the neck of the receiver, and a circular hole made in it sufficient to admit the beak of the retort. The curved tubes of a Woulfe's apparatus, when not fitted accurately by grinding, may be also fixed by means of corks. After the parts are thus firmly joined, the luting must be neatly and closely applied over the junctures; and the whole covered with slips of wet bladder, or with linen spread with one or other of the above described cements. The application of the lutes, although apparently very simple, yet requires some management, lest the luting of one juncture should disturb another already luted, which is apt to happen when applying the fillets and ligatures.

[1] *Aikin's Dictionary of Chemistry.*