G. XVIII. *Chromium.* Precipitate by triple prussiate and hydrosulphuret green, and by infusion of galls brown.

G. XIX. *Molybdenum.* Solutions blue, precipitate by triple prussiate and tincture of galls brown.

G. XX. *Tungsten.* Unknown.

G. XXI. *Arsenic.* Precipitate by water and triple prussiate white, by hydrosulphuret of potass yellow, by sulphate of copper green, by nitrate of silver yellow.

G. XXII. *Columbium.* Colourless; precipitate by alkaline carbonates and zinc white, by triple prussiate green, by hydrosulphuret of ammonia chocolate, and by tincture of galls orange.

G. XXIII. *Iridium.* Muriatic and sulphuric solution green, nitric red; precipitate by alkalies green and red.

G. XXIV. *Osmium.* Alkaline solution coloured purple and vivid blue by infusion of galls.

G. XXV. *Rhodium.* Triple salt with soda and muriatic acid not precipitated by prussiate of potass, muriate or hydrosulphuret of ammonia, or alkaline carbonates, but by pure alkalies yellow.

G. XXVI. *Palladium.* Acid solutions red; precipitated by prussiate of mercury yellowish-white; by prussiate of potass, brown.

G. XXVII. *Cerium.* Acid solutions precipitated by alkalies white.

SECT. II.

PHARMACEUTICAL OPERATIONS.

COLLECTION AND PRESERVATION OF SIMPLES.

381. EACH of the kingdoms of nature furnishes substances which are employed in medicine, either in their natural state, or after they have been prepared by the art of pharmacy.

382. In collecting these, attention must be paid to select such as are most sound and perfect, to separate from them whatever is injured or decayed, and to free them from all foreign matters.

383. Those precautions must be taken which are best fitted for preserving them They must, in general, be defended from the effects of moisture, too great heat or cold, and confined air.

384. When their activity depends on volatile principles, they must be preserved from the contact of the air as much as possible.

385. As the vegetable kingdom presents us with the greatest number of simples, and the substances belonging to it are the least constant in their properties, and most subject to decay, it becomes necessary to give a few general rules for their collection and preservation.

386. Vegetable matters should be collected in the countries where they are indigenous; and those which grow wild, in dry soils and high situations, fully exposed to the air and sun, are in general to be preferred to those which are cultivated, or which grow in moist, low, shady, or confined places.

387. Roots which are annual, should be collected before they shoot out their stalks or flowers; biennial roots in the autumn of the first, or spring of the second year; perennial roots either in spring before the sap has begun to mount, or in harvest after it has returned.

388. Those which are worm eaten, except some resinous roots, or which are decayed, are to be rejected. The others are immediately to be cleaned with a brush and cold water, letting them lie in it as short a time as possible; and the fibres and little roots, when not essential, are to be cut away.

389. Roots which consist principally of fibres, and have but a small tap, may be immediately dried. If they be juicy, and not aromatic, this may be done by heat, not exceeding 100° of Fahrenheit; but if aromatic, by simply exposing them, and frequently turning them in a current of dry air; if very thick and strong, they are to be split or cut into slices, and strung upon threads; if covered with a tough bark, they may be peeled fresh, and then dried. Farinaceous roots are to be dipt in boiling water before they are dried. Such as lose their virtues by drying, or are directed to be preserved in a fresh state, are to be kept buried in dry sand. Ginger is peeled and preserved in syrup.

390. No very general rule can be given for the collection of herbs and leaves: some of them acquiring activity from their age; and others, as the mucilaginous leaves, from the same cause, losing the property for which they are officinal. Aromatics are to be collected after the flower-buds are formed; annuals, not aromatic, when they are about to flower, or

when in flower; biennials, before they shoot; and perennials, before they flower, especially if their fibres become woody.

391. They are to be gathered in dry weather, after the dew is off them, or in the evening, before it falls, and are to be freed from decayed, or foreign leaves. They are usually tied in bundles, and hung up in a shady, warm, and airy place; or spread upon the floor, and frequently turned. If very juicy, they are laid upon a sieve, and dried by a gentle degree of artificial warmth.

392. Sprouts are collected before the buds open; and stalks are gathered in autumn.

393. Barks and woods are collected in spring or in autumn, when the most active parts of the vegetable are concentrated in them. Spring is preferred for resinous barks, and autumn for the others which are not resinous, but rather gummy. Barks should be taken from young trees, and freed from decayed parts, and all impurities.

394. The same rules are to be followed in collecting woods, which, however, must not be taken from very young trees. Among the resinous woods, the heaviest, which sink in water, are selected. The alburnum is to be rejected.

395. Flowers are to be collected in clear dry weather, before noon, but after the dew is off, either when they are just about to open, or immediately after they have opened. Of some the petals only are preserved, and the colourless claws are even cut away; of others whose calyx is odorous, the whole flower is kept. Flowers which are too small to be pulled singly, are dried with part of the stalk; these are called heads or tops.

396. Flowers are to be dried nearly in the same manner as leaves, but more quickly, and with more attention. As they must not be exposed to the sun, it is best done by a slight degree of artificial warmth; and in some cases they should be put up in paper bags. When they lose their colour and smell, they are unfit for use.

397. Seeds and fruits, unless when otherwise directed, are to be gathered when ripe, but before they fall spontaneously. The emulsive and farinaceous seeds are to be dried in an airy, cool place; the mucilaginous seeds by the heat of a stove. Some pulpy fruits are freed from their core and seeds, strung upon thread, and dried artificially, by exposing them repeatedly to the heat of a stove. They are in general best preserved in their natural coverings, although some, as the colocynth, are peeled, and others, as the tamarind, immersed in syrup. Many seeds and fruits are apt to spoil, or become rancid;

and as they are then no longer fit for medical use, no very large quantity of them should be collected at a time.

398. The proper drying of vegetable substances is of the greatest importance. It is often directed to be done in the shade, and slowly, that the volatile and active particles may not be dissipated by too great heat: but this is an error; for they always lose infinitely more by slow than by quick drying. When, on account of the colour, they cannot be exposed to the sun, and the warmth of the atmosphere is insufficient, they should be dried by an artificial warmth, less than 100° Fahrenheit, and exposed to a free current of air. When perfectly dry and friable, they have little smell; but after being kept some time, they attract moisture from the air, and regain their proper odour.

399. The boxes and drawers in which vegetable substances are kept, should not impart to them any smell or taste; and more certainly to avoid this, they should be lined with white paper. Such as are volatile, of a delicate texture, or subject to suffer from insects, must be kept in well-covered glasses. Fruits and oily seeds, which are apt to become rancid, must be kept in a cool and dry, but by no means in a warm or moist place.

400. Oily seeds, odorous plants, and those containing volatile principles, should be collected fresh every year; others, whose properties are more permanent, and not subject to decay, will keep for several years.

401. Vegetables collected in a moist and rainy season are in general watery, and apt to spoil. In a dry season, on the contrary, they contain more oily and resinous particles, are more active, and keep much better.

MECHANICAL OPERATIONS OF PHARMACY.

a. The determination of the weight and bulk of bodies.
b. The division of bodies into more minute particles.
c. The separation of their integrant parts by mechanical means.
d. Their mixture, when not attended by any chemical action.

WEIGHTS AND MEASURES.

402. The quantities of substances employed in pharmaceutical operations are most accurately determined by the process called weighing. For this purpose, there should be sets of beams and scales of different sizes; and it would be advisable to have a double set, one for ordinary use, and another for oc-

casions when greater accuracy is necessary. A good beam should remain in equilibrium both by itself and when the scales are suspended, one to either end indifferently; and it should turn sensibly with a very small proportion of the weight with which it is loaded. Balances should be defended as much as possible from acid and other corrosive vapours, and should not be overloaded, or left suspended longer than is necessary, as their delicacy is thereby very much impaired. It is unfortunately not unnecessary to mention, that the scales and weights, as well as measures, funnels, mortars, &c. should be kept extremely clean. Some nice apothecaries have their scales made of glass, ivory, or tortoise shell; but in many shops the common brass scales are disgustingly filthy, and covered with verdigris.

403. The want of uniformity of weights and measures is attended with many inconveniences. In this country, druggists and grocers sell by avoirdupois weight; and the apothecaries are directed to sell by troy weight, although, in fact, they seldom use the troy weight for more than two drachms. But as the troy pound is less than the avoirdupois, and the ounce and drachm greater, numerous and culpable errors must arise. Comparative tables of the value of the troy, avoirdupois, and new French decimal weights, are given in the Appendix.

404. The errors arising from the promiscuous use of weights and measures, have induced the Edinburgh college to reject the use of measures entirely, and to direct that the quantity of every fluid, as well as solid, shall be determined by troy weight: but as the London and Dublin colleges sanction the use of measures, and as, from the much greater facility of their employment, apothecaries will always use them, tables of measures are also inserted in the Appendix.

405. For measuring fluids, the graduated glass measures are always to be preferred: they should be of different sizes, according to the quantities they are intended to measure. Elastic fluids are also measured in glass tubes and jars, graduated by inches and their decimals.

406. The practice of administering active fluids by drops has been long known to be inaccurate; but the extent of the evil has been only lately ascertained, by the accurate experiments of Mr Shuttleworth, surgeon, of Liverpool. Not only do the drops of different fluids from the same vessel, and of the same fluids from different vessels, differ much in size; but it appears that the drops of the same fluid differ, even to the extent of a third, from different parts of the lip of the same vessel. The custom of dropping active fluids should, there-

fore, be abolished entirely; and, as weighing is too troublesome and difficult for general use, we must have recourse to small measures, accurately graduated, in the manner of Lane's *drop* measure, and the *grain* measure recommended by the Edinburgh college; but we must not be misled by their names; for they are measures of bulk, not of drops or of grains.

SPECIFIC GRAVITY.

407. Specific gravity is the comparative weight of equal bulks of different bodies. As a standard of comparison, distilled water has been generally assumed as unity. The specific gravity of any solid is ascertained, by comparing the weight of the body in the air with its weight when suspended in water. The quotient obtained by dividing its weight in air, by the difference between its weight in air and its weight in water, is its specific gravity. The specific gravity of fluids may be ascertained by comparing the weight of a solid body, such as a piece of crystal, when immersed in distilled water, with its weight when immersed in the fluid we wish to examine; by dividing its loss of weight in the fluid by its loss of weight in the water, the quotient is the specific gravity of the fluid: or a small phial, containing a known weight of distilled water, may be filled with the fluid to be examined, and weighed, and by dividing the weight of the fluid by the weight of the water, the specific gravity is ascertained.

Although these are the only general principles by which specific gravities are ascertained, yet as the result is always influenced by the state of the thermometer and barometer at the time of the experiments, and as the manipulation is a work of great nicety, various ingenious instruments have been contrived to render the process and calculation easy. Of all these, the gravimeter of Morveau seems to deserve the preference.

It would be of material consequence to science and the arts, if specific gravities were always indicated by the numerical term expressing their relation to the specific gravity of distilled water. This, however, is unfortunately not the case. The excise in this country collect the duties paid by spiritous liquors, by estimating the proportion which they contain of a standard spirit, about 0.933 in specific gravity, which they call hydrometer proof; and they express the relation which spirits of a different strength have to the standard spirit, by saying that they are above or under hydrometer proof. Thus, one to six, or one in seven below hydrometer proof, means, that it is equal in strength to a mixture of six parts of proof spirit with one of water.

The only other mode of expressing specific gravities, which it is necessary to notice, is that of Baumé's areometer, as it is often used in the writings of the French chemists, and is little understood in this country. For substances heavier than water, he assumes the specific gravity of distilled water as zero, and graduates the stem of his instrument downwards, each degree being supposed by him to express the number of parts of muriate of soda contained in a given solution; which, however, is not at all the case. For substances lighter than water the tube is graduated upwards, and this zero is afforded by a solution of 1 of salt in 9 water. In the appendix, tables are given of the specific gravities, corresponding with all the degrees of both of these areometers, from Nicolson's Journal.

The specific gravity of the gases differs so much from that of water, that the lightest of them, hydrogen gas, has lately been assumed as unity in regard to this class of substances.

MECHANICAL DIVISION.

408. By mechanical division, substances are reduced to a form better adapted for medical purposes; and by the increase of their surface, their action is promoted, both as medical and chemical agents.

409. It is performed by cutting, bruising, grinding, grating, rasping, filing, pulverization, trituration, and granulation, by means of machinery or of proper instruments.

410. *Pulverization* is the first of these operations that is commonly employed in the apothecary's shop. It is performed by means of pestles and mortars. The bottom of the mortars should be concave; and their sides should neither be so inclined as not to allow the substance operated on to fall to the bottom between each stroke of the pestle, nor so perpendicular as to collect it too much together, and to retard the operation. The materials of which the pestles and mortars are formed, should resist both the mechanical and chemical action of the substances for which they are used. Wood, iron, marble, siliceous stones, porcelain, and glass, are all employed; but copper, and metals containing copper, are to be avoided.

411. They should be provided with covers, to prevent the finest and lightest parts from escaping, and to defend the operator from the effects of disagreeable or noxious substances. But these ends are more completely attained, by tying a piece

of pliable leather round the pestle, and round the mouth of the mortar. It must be closely applied, and at the same time so large, as to permit the free motion of the pestle.

412. In some instances, it will be even 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 very acrid particles which arise may be carried from him.

413. The addition of a little water or spirit of wine, or of a few almonds, to very light and dry substances, will prevent their flying off. But almonds are apt to induce rancidity, and powders are always injured, by the drying which is necessary when they have been moistened. Water must never be added to substances which absorb it, or are rendered cohesive by it.

414. Too great a quantity of any substance must never be put into the mortar at a time, as it very much retards the operation.

415. All vegetable substances must be previously dried. Resins and gummy resins, which become soft in summer, must be powdered in very cold weather, and must be beaten gently, or they will be converted into a paste, instead of being powdered. Woods, roots, barks, horn, bone, ivory, &c. should be previously cut, split, chipped, or rasped. Fibrous woods and roots should be finely shaved after their bark is removed, for otherwise their powders will be full of hair-like filaments, which can scarcely be separated. Some substances will even require to be moistened with mucilage of tragacanth, or of starch, and then dried before they can be powdered. Camphor may be conveniently powdered by the addition of a little spirit of wine, or almond oil. The emulsive seeds cannot be reduced to powder, unless some dry powder be added to them. To aromatic oily substances, sugar is the best addition.

416. All impurities and inert parts having been previously separated, the operation must be continued and repeated upon vegetable substances, till no residuum is left. The powders obtained at different times must then be intimately mixed together, so as to bring the whole to a state of perfect uniformity.

417. Very hard stony substances must be repeatedly heated to a red heat, and then suddenly quenched in cold water, until they become sufficiently friable. Some metals may be powdered hot in a heated iron mortar, or may be rendered brittle by alloying them with a little mercury.

418. *Trituration* is intended for the still more minute division of bodies. It is performed in flat mortars of glass, agate,

or other hard materials, by giving a rotatory motion to the pestle; or on a levigating stone, which is generally of porphyry, by means of a muller of the same substance. On large quantities it is performed by rollers of hard stone, turning horizontally upon each other, or by one vertical roller turning on a flat stone.'

419. *Levigation* differs from trituration only in the addition of water or spirit of wine to the powder operated upon, so as to form the whole mass into a kind of paste, which is rubbed until it be of sufficient smoothness or fineness. Earths, and some metallic substances, are levigated.

420. The substances subjected to this operation are generally previously powdered or ground.

421. *Granulation* is employed for the mechanical division of some metals. It is performed either by stirring the melted metal with an iron rod until it cools, or by pouring it into water, and stirring it continually as before, or by pouring it into a covered box, previously well rubbed with chalk, and shaking it until the metal cools, when the rolling motion will be converted into a rattling one. The adhering chalk is then to be washed away.

MECHANICAL SEPARATION.

422. *Sifting.* From dry substances, which are reduced to the due degree of minuteness, the coarser particles are to be separated by sieves of iron-wire, hair-cloth, or gauze, or by being dusted through bags of linen. For very light and valuable powders, or acrid substances, compound sieves, having a close lid and receiver, must be used. The particles which are not of sufficient fineness to pass through the interstices of the sieve, may be again powdered.

423. *Elutriation* is performed on mineral substances, on which water has no action, for separating them from foreign particles and impurities, of a different specific gravity, in which case they are said to be washed; or for separating the impalpable powders, obtained by trituration and levigation from the coarser particles. This process depends upon the property that very fine or light powders have of remaining for some time suspended in water; and is performed by diffusing the powder or paste formed by levigation through plenty of water, letting it stand a sufficient time, until the coarser particles settle at the bottom, and then pouring off the liquid in which the finer or lighter particles are suspended. Fresh water may be poured on the residuum, and the operation repeated; or the coarser particles which fall to the bottom may be previously levigated a second time. The fine

powder which is washed over with the water is separated from it, by allowing it to subside completely, and by decanting off the water very carefully.

424. *Decantation* is very frequently made use of for separating the clear from the turbid part of a fluid, and for separating fluids from solids, which are specifically heavier, especially when the quantity is very large, or the solid so subtile as to pass through the pores of most substances employed for filtration, or the liquid so acrid as to corrode them.

425. *Filtration.* For the purposes of separating fluids from solids, straining and filtration are often used. These differ only in degree, and are employed when the powder either does not subside at all, or too slowly and imperfectly for decantation.

426. The instruments for this purpose are of various materials, and must in no instance be acted upon by the substances for which they are employed. Fats, resins, wax and oils, are strained through hemp or flax, spread evenly over a piece of wire-cloth or net stretched in a frame. For saccharine and mucilaginous liquors, fine flannel may be used; for some saline solutions, linen. Sponge in some instances forms a convenient filter. Where these are not fine enough, unsized paper is employed, but it is extremely apt to burst by hot watery liquors. Very acrid liquors, such as acids, are filtered by means of a glass funnel, filled with powdered quartz, a few of the larger pieces being put in the neck, smaller pieces over these, and the fine powder placed over all. The porosity of this last filter retains much of the liquor; but it may be obtained by gently pouring on it an equal quantity of distilled water; the liquor will then pass through, and the water will be retained in its place.

427. Water may be filtrated in large quantities through basins of porous stone, or artificial basins of nearly equal parts of fine clay and coarse sand. In large quantities it may be easily purified *per ascensum*, the purified liquor and impurities thus taking opposite directions. The simplest apparatus of this kind is a barrel, divided perpendicularly, by a board perforated with a row of holes along the lower edge. Into each side, as much well washed sand is put as will cover these holes an inch or two, over which must be placed a layer of pebbles to keep it steady. The apparatus is now fit for use. Water poured into the one half will sink through the sand in that side, pass through the holes in the division to the other, and rise through the sand in the other half, from which it may be drawn by a stop-cock.

428. The size of the filters depends on the quantity of mat-

ter to be strained. When large, the flannel or linen is formed into a conical bag, and suspended from a hoop or frame; the paper is either spread on the inside of these bags, or folded into a conical form, and suspended by a funnel. It is of advantage to introduce glass rods or quills between the paper and funnel, to prevent them from adhering too closely.

429. What passes first is seldom fine enough, and must be poured back again, until by the swelling of the fibres of the filter, or filling up of its pores, the fluid acquires the requisite degree of limpidity. The filter is sometimes covered with charcoal powder, which is a useful addition to muddy and deep-coloured liquors. The filtration of some viscid substances is much assisted by heat.

430. *Expression* is a species of filtration, assisted by mechanical force. It is principally employed to obtain the juices of fresh vegetables, and the unctuous vegetable oils. It is performed by means of a screw press, with plates of wood, iron, or tin. The subject of the operation is previously beaten, ground, or bruised. It is then inclosed in a bag, which must not be too much filled, and introduced between the plates of the press. The bags should be of hair-cloth, or canvas inclosed in hair-cloth. Hempen and woollen bags are apt to give vegetable juices a disagreeable taste. The pressure should be gentle at first, and increased gradually.

431. Vegetables intended for this operation should be perfectly fresh, and freed from all impurities. In general they should be expressed as soon as they are bruised, for it disposes them to ferment; but subacid fruits give a larger quantity of juice, and of finer quality, when they are allowed to stand some days in a wooden or earthen vessel after they are bruised. To some vegetables which are not juicy enough, the addition of a little water is necessary. Lemons and oranges must be peeled, as their skins contain a great deal of essential oil, which would mix with the juice. The oil itself may be obtained separately, by expression with the fingers on a piece of glass.

432. For unctuous seeds iron plates are used; and it is customary not only to heat the plates, but to warm the bruised seeds in a kettle over the fire, after they have been sprinkled with water, as by these means the product is increased, and the oil obtained is more limpid. But as the oils obtained in this way are more disposed to rancidity, this process should either be laid aside altogether, or changed to exposing the bruised seeds, inclosed in a bag, to the steam of hot water.

433. *Despumation* is generally practised on thick and clammy liquors, which contain much slimy and other impurities,

not easily separable by filtration. The scum is made to arise, either by simply heating the liquor, or by *clarifying* it, which last is done by mixing with the liquor, when cold, white of egg well beaten with a little water, which on being heated coagulates, and rises to the surface, carrying with it all the impurities. The liquor may now be filtered with ease, or may be skimmed with a perforated laddle. Spiritous liquors are clarified, without the assistance of heat, by means of isinglass dissolved in water, or of any albuminous fluid, as milk, which coagulates with the action of alcohol. Some expressed juices, as those of all the antiscorbutic plants, are instantly clarified by the addition of any vegetable acid, as the juice of bitter oranges.

434. Fluids can only be separated from each other, when they have no tendency to combine, and when they differ in specific gravity. The separation may be effected by skimming off the lighter fluid with a silver or glass spoon; or by drawing it off by a syringe or syphon; or by means of a glass separatory, which is an instrument having a projecting tube, terminating in a very slender point, through which the heavier fluid alone is permitted to run; or by means of the capillary attraction of a spongy woollen thread; for no fluid will enter a substance whose pores are filled by another, for which it has no attraction; and, lastly, upon the same principle, by means of a filter of unsized paper, previously soaked in one of the fluids, which in this way readily passes through it, while the other remains behind.

435. *Mechanical mixture* is performed by agitation, trituration, or kneading; but these will be best considered in treating of the forms in which medicines are exhibited.

APPARATUS.

436. Before entering on the chemical operations, it will be necessary to make a few remarks on the instruments employed in performing them. They may be divided into

a. The vessels in which the effects are performed;
b. Fuel, or the means of producing heat; and
c. The means of applying and regulating the heat, or lamps and furnaces.

VESSELS.

437. The vessels, according to the purposes for which they are intended, vary

a. In form; and
b. In materials.

438. The different forms will be best described when treating of the particular operations.

439. No substance possesses properties which render it proper to be employed as a material in every instance. We are therefore obliged to select those substances which possess the properties more especially required in the particular operations for which they are intended.

440. The properties most generally required, are

a. The power of resisting chemical agents;
b. Transparency;
c. Compactness;
d. Strength;
e. Fixity and infusibility;
f. And the power of bearing sudden variations of temperature without breaking.

441. The metals in general possess the four last properties in considerable perfection, but they are all opaque. Iron and copper are apt to be corroded by chemical agents, and the use of the latter is often attended with dangerous consequences. These objections are in some measure, but not entirely, removed by tinning them. Tin and lead are too fusible. Platinum, gold, and silver, resist most of the chemical agents, but their expence is an insurmountable objection to their general use.

442. Good earthen ware resists the greatest intensity of heat, but is deficient in all the other properties. The basis of all kinds of earthen ware is clay, which possesses the valuable quality of being very plastic when wrought with water, and of becoming extremely hard when burnt with an intense heat. But it contracts so much by heat, that it is extremely apt to crack and split, on being exposed to sudden changes of temperature; it is therefore necessary to add some substance which may counteract this property. Siliceous sand, clay burnt with a very intense heat, and then reduced to powder, and plumbago, are occasionally used. These additions, however, are attended with other inconveniences; plumbago, especially, is liable to combustion, and sand diminishes the compactness, so that it becomes necessary to glaze most kinds of earthen ware; but when glazed, they are acted upon by chemical agents. The vessels manufactured by Messrs Wedgwood are the best of this description, except those of porcelain, which are too expensive.

443. Glass possesses the three first qualities in an eminent degree, and may be heated red hot without melting. Its greatest inconvenience is its disposition to crack, or break in

pieces, when suddenly heated or cooled. As this is occasioned by its unequal expansion or contraction, glass vessels should be made very thin, and of a round form. They should also be well annealed, that is cooled very slowly, when blown, by placing them immediately in a heated oven, while they are yet in a soft state. When ill annealed, or cooled suddenly, glass is apt to fly in pieces on the slightest change of temperature, or touch of a sharp point. We sometimes take advantage of this imperfection; for by means of a red-hot wire, charcoal, or bit of a tobacco-pipe, glass-vessels may be cut into any shape. When there is not a crack already in the glass, the point of the wire is applied near the edge, a crack is formed, which is afterwards easily led in any direction.

444. Reaumeur's porcelain, on the contrary, is glass, which by surrounding it with hot sand, is made to cool so slowly, that it assumes a crystalline texture, which destroys its transparency, but imparts to it every other quality wished for in chemical vessels. The coarser kinds of glass are commonly used in making it; but as there is no manufacture of this valuable substance, its employment is still very limited.

LUTES.

445. Lutes also form a necessary part of chemical apparatus. They are compositions of various substances, intended,

a. To close the joinings of vessels;
b. To coat glass vessels.
c. To line furnaces.

446. Lutes of the first description are commonly employed to confine elastic vapours. They should therefore possess the following properties:

a. Viscidity, plasticity, and compactness;
b. The power of resisting acrid vapours;
c. The power of resisting certain degrees of heat.

447. The viscidity of lutes depends on the presence either of

a. Unctuous or resinous substances;
b. Mucilaginous substances; or
c. Clay or lime.

448. Lutes of the first kind possess the two first class of properties in an eminent degree; but they are in general so fusible, that they cannot be employed when they are exposed

even to very low degrees of heat, and they will not adhere to any substance that is at all moist. Examples.

a. Eight parts of yellow wax, melted with one of oil of turpentine, with or without the addition of resinous substances, according to the degree of pliability and consistence required. Lavoisier's lute.

b. Four parts of wax, melted with two of varnish and one of olive oil. Saussure's lute.

c. Three parts of powdered clay, worked up into a paste, with one of drying oil, or, what is better, amber varnish. The drying oil is prepared by boiling 22.5 parts of litharge in 16 of linseed oil until it be dissolved. Fat lute.

d. Chalk and oil, or glazier's putty, is well fitted for luting tubes permanently into glass vessels, for it becomes so hard that it cannot be easily removed.

e. Equal parts of litharge, quicklime, and powdered clay, worked into a paste with oil varnish, is sometimes applied over the cracks in glass vessels, so as to fit them for some purposes.

f. Melted pitch and brick dust.

449. Mucilaginous substances, such as flour, starch, gum, and glue, mixed with water, are sufficiently adhesive, are dried by moderate degrees of heat, and are easily removed after the operation, by moistening them with water; but a high temperature destroys them, and they do not resist corrosive vapours. The addition of an insoluble powder is often necessary to give them a sufficient degree of consistency. Examples.

a. Slips of bladder, softened in water, and applied with the inside next the vessels. They are apt, however, from their great contraction in drying, to break weak vessels.

b. One part of gum-arabic with six or eight of chalk, formed into a paste with water.

c. Flour worked into a paste with powdered clay or chalk.

d. Almond or linseed meal formed into a paste with mucilage or water.

e. Quicklime in fine powder, hastily mixed with white of egg, and instantly applied, sets very quickly, but becomes so hard that it can scarcely be removed.

f. Slaked lime in fine powder, with glue, does not set so quickly as the former.

g. The cracks of glass vessels may be cemented by daubing them and a suitable piece of linen over with white of egg, strewing both over with finely powdered quicklime, and instantly applying the linen closely and evenly.

450. Earthy lutes resist very high temperatures, but they become so hard that they can scarcely be removed, and often harden so quickly after they are mixed up, that they must be applied immediately. Examples.

a. Quicklime well incorporated with a sixth part of muriate of soda.

b. Burnt gypsum, made up with water.

c. One ounce of borax dissolved in a pound of boiling water, mixed with a sufficient quantity of powdered clay. Mr Watt's fire lute.

d. One part of clay with four of sand, formed into a paste with water. This is also used for coating glass vessels, in order to render them stronger, and capable of resisting intense heat. It is then made into a very thin mass, and applied in successive layers, taking care that each coat be perfectly dry before another be laid on.

451. The lutes for lining furnaces will be described when treating of furnaces.

452. The junctures of vessels which are to be luted to each other, should previously be accurately and firmly fitted, by introducing between them, when necessary, short pieces of wood or cork, or, if the disproportion be very great, by means of a cork fitted to the one vessel, having a circular hole bored through it, through which the neck of the other vessel or tube may pass.

453. After being thus fitted, the lute is either applied very thin, by spreading it on slips of linen or paper, and securing it with thread; or if it is a paste lute, it is formed into small cylinders, which are successively applied to the junctures, taking care that each piece be made to adhere firmly and perfectly close in every part before another is put on. Lastly, the whole is secured by slips of linen or bladder.

454. In many cases, to permit the escape of elastic vapours, a small hole is made through the lute with a pin, or the lute is perforated by a small quill, fitted with a stopper.

HEAT AND FUEL.

455. As caloric is an agent of the most extensive utility in the chemical operations of pharmacy, it is necessary that we

should be acquainted with the means of employing it in the most economical and efficient manner.

456. The rays of the sun are used in the drying of many vegetable substances; and the only attentions necessary, are to expose as large a surface as possible, and to turn them frequently, that every part may be dried alike. They are also sometimes used for promoting spontaneous evaporation.

457. Combustion is a much more powerful and certain source of heat. Alcohol, oil, tallow, wood, turf, coal, charcoal, and coke, are all occasionally employed.

458. Alcohol, oil, and melted tallow, can only be burnt on porous wicks, which draw up a portion of the fluid to be volatilized and inflamed. Fluid inflammables are therefore burnt in lamps of various constructions. But although commonly used to produce light, they afford an uniform, but not high temperature. This may however be increased, by increasing the number and size of the wicks. Alcohol produces a steady heat, no soot, and, if strong, leaves no residuum. Oil gives a higher temperature, but on a common wick produces much smoke and soot. These are diminished, and the light and heat increased, by making the surface of the flame bear a large proportion to the centre; which is best done by a cylindrical wick, so contrived that the air has free access both to the outside and inside of the cylinder, as in Argand's lamp, invented by Mr Bolton of Birmingham. In this way, oil may be made to produce a considerable temperature, of great uniformity, and without the inconvenience of smoke.

459. Wicks have the inconvenience of being charred by the high temperature to which they are subjected, and becoming so clogged as to prevent the fluid from rising in them. They must then be trimmed; but this is seldomer necessary with alcohol and fine oils than with the coarser oils. Lamps are also improved by adding a chimney to them. It must admit the free access of air to the flame, and then it increases the current, confines the heat, and steadies the flame. The intensity of the temperature of flame may be greatly increased by forcing a small current of hot air through it, as by the blowpipe.

460. Wood, turf, coal, charcoal, and coke, solid combustibles, are burnt in grates and furnaces. Wood has the advantage of kindling readily, but affords a very unsteady temperature, is inconvenient from its flame, smoke, and soot, and requires much attention. The heavy and dense woods give the greatest heat, burn longest, and leave a dense charcoal.

461. Dry turf gives a steady heat, and does not require so much attention as wood; but it consumes fast, its smoke is

copious and penetrating, and the empyreumatic smell which it imparts to every thing it comes in contact with, adheres to them with great obstinacy. The heavy turf of marshes is preferable to the light surface turf.

462. Coal is the fuel most commonly used in this country. Its heat is considerable, and sufficiently permanent, but it produces much flame and smoke.

463. Charcoal, especially of the dense woods, is a very convenient and excellent fuel. It burns without flame or smoke, and gives a strong, uniform, and permanent heat, which may be easily regulated, especially when it is not in too large pieces, and is a little damp. But it is costly, and burns quickly.

464. Coke, or charred coal, possesses similar properties with charcoal; it is less easily kindled, but is capable of producing a higher temperature, and burns more slowly.

465. When an open grate is used for chemical purposes, it should be provided with cranes to support the vessels, that they may not be overturned by the burning away of the fuel.

FURNACES.

466. In all furnaces, the principal objects are, to produce a sufficient degree of heat, with little consumption of fuel, and to be able to regulate the degree of heat.

467. An unnecessary waste of fuel is prevented by forming the sides of the furnace of very imperfect conductors of caloric, and by constructing it so that the subject operated on may be exposed to the full action of the fire.

468. The degree of heat is regulated by the quantity of air which comes in contact with the burning fuel. The quantity of air is in the compound ratio of the size of the aperture through which it enters, and its velocity. The velocity may be increased by mechanical means, as by bellows, or by increasing the height and width of the chimney.

369. The size and form of furnaces, and the materials of which they are constructed, are various, according to the purposes for which they are intended.

470. The essential parts of a furnace are,

a. A body for the fuel to burn in;
b. A grate for it to burn upon;
c. An ash-pit to admit air and receive the ashes;
d. A chimney for carrying off the smoke and vapours.

471. The ash-pit should be perfectly close, except the door, which should be furnished with a register-plate, to regulate the quantity of air admitted.

472. The bars of the grate should be triangular, and placed with an angle pointed downwards, and not above half an inch distant. The grate should be fixed on the outside of the body.

473. The body may be cylindrical or elliptical, with apertures for introducing the fuel and the subjects of the operation, and for conveying away the smoke and vapours.

474. When the combustion is supported by the current of air naturally excited by the burning of the fuel, it is called a wind furnace; when it is accelerated by increasing the velocity of the current by bellows, it forms a blast-furnace; and when the body of the furnace is covered with a dome, which terminates in the chimney, it constitutes a reverberatory furnace.

475. Furnaces are either fixed and built of fire-brick, or portable, and fabricated of plate-iron. When of iron, they must be lined with some badly conducting and refractory substance, both to prevent the dissipation of heat, and to defend the iron against the action of the fire. A mixture of scales of iron and powdered tiles, worked up with blood, hair, and clay, is much recommended; and Professor Hagen says, that it is less apt to split and crack when exposed at once to a violent heat, than when dried gradually, according to the common directions. Dr Black employed two different coatings. Next to the iron, he applied a composition of three parts by weight of charcoal, and one of fine clay, first mixed in the state of fine powder, and then worked up with as much water as permitted the mass to be formed into balls, which were applied to the sides of the furnace, and beat very firm and compact with the face of a broad hammer, to the thickness of about one inch and a half in general, but so as to give an elliptical form to the cavity. Over this, another lute, composed of six or seven parts of sand, and one of clay, was applied, in the same manner, to the thickness of about half an inch. These lutes must be allowed to become perfectly dry before the furnace is heated, which should at first be done gradually. They may also be lined with fire bricks of a proper form, accurately fitted and well-cemented together before the top-plate is screwed on.

476. The general fault of furnaces is, that they admit so much air, as to prevent us from regulating the temperature, which either becomes too violent and unmanageable, or when more cold air is admitted than what is necessary for supporting the combustion, the heat is carried off, and the temperature cannot be raised sufficiently. The superior merit of Dr Black's furnace consists in the facility with which the admis-

sion of air is regulated; and every attempt hitherto made to improve it, by increasing the number of its apertures, have in reality injured it.

477. Heat may be applied to vessels employed in chemical operations,

a. Directly, as in the open fire and reverberatory furnace;
b. Or through the medium of sand; the sand bath;
c. Of water; the water bath;
d. Of steam; the vapour bath;
e. Of air, as in the muffle.

CHEMICAL OPERATIONS.

478. In all chemical operations, combination takes place, and there are very few of them in which decomposition does not also occur. For the sake of method, we shall consider them as principally intended to produce,

a. Change in the form of aggregation;
b. Combination;
c. Decomposition.

479. The form of aggregation may be altered by,

a. Fusion;
b. Vaporization;
c. Condensation;
d. Congelation;
e. Coagulation.

480. *Liquefaction* is commonly employed to express the melting of substances, as tallow, wax, resin, &c. which pass through intermediate states of softness before they become fluid.

481. *Fusion* is the melting of substances which pass immediately from the solid to the fluid state, as the salts and the metals, except iron and platinum. Substances differ very much in the degrees of their fusibility; some, as water and mercury, existing as fluids in the ordinary temperatures of the atmosphere; while others, as the pure earths, cannot be melted by any heat we can produce.

482. When a substance acquires by fusion a degree of transparency, a dense uniform texture, and great brittleness, and exhibits a conchoidal fracture, with a specular surface, and the edges of the fragments very sharp, it is said to be *vitrified.*

483. In general, simple substances are less fusible than compounds; thus the simple earths cannot be melted singly,

but when mixed are easily fused. The additions which are sometimes made to refractory substances to promote their fusion, are termed *fluxes*.

484. These fluxes are generally saline bodies.

a. The alkalies, potass, and soda, promote powerfully the fusion of siliceous stones; but they are only used for accurate experiments. The *white flux* is a mixture of a little potass with carbonate of potass, and is prepared by deflagrating together equal parts of nitrate of potass and supertartrate of potass. When an oxide is at the same time to be reduced, the *black* flux is to be preferred, which is produced by the deflagration of two parts of supertartrate of potass, and one of nitrate of potass. It differs from the former only in containing a little charcoal. Soap promotes fusion by being converted by the fire into carbonate of soda and charcoal.

b. Aluminous stones have their fusion greatly promoted by the addition of sub-borate of soda.

c. Muriate of soda, the mixed phosphate of soda and ammonia, and other salts, are also occasionally employed.

485. An open fire is sufficient to melt some substances; others require the heat of a furnace.

486. The vessels in which fusion is performed, must resist the heat necessary for the operation. In some instances, an iron or copper ladle or pot may be used; but most commonly crucibles are employed. *Crucibles* are of various sizes.—The large crucibles are generally conical, with a small spout for the convenience of pouring out: the small ones are truncated triangular pyramids, and are commonly sold in nests.

487. The Hessian crucibles are composed of clay and sand, and when good, will support an intense heat for many hours, without softening or melting; but they are disposed to crack when suddenly heated or cooled. This inconvenience may be on many occasions avoided, by using a double crucible, and filling up the interstice with sand, or by covering the crucible with a lute of clay and sand, by which means the heat is transmitted more gradually and equally. Those which give a clear sound when struck, and are of an uniform thickness, and have a reddish-brown colour, without black spots, are reckoned the best.

488. Wedgwood's crucibles are made of clay mixed with baked clay finely pounded, and are in every respect superior to the Hessian, but they are expensive.

489. The black lead crucibles, formed of clay and plumba-

go, are very durable, resist sudden changes of temperature, and may be repeatedly used; but they are destroyed when saline substances are melted in them, and suffer combustion when exposed red-hot to a current of air.

490. When placed in a furnace, crucibles should never be set upon the bars of the grate, but always upon a support. Dr Kennedy found the hottest part of a furnace to be about an inch above the grate. They may be covered, to prevent the fuel or ashes from falling into them, with a lid of the same materials, or with another crucible inverted over them.

491. When the fusion is completed, the substance may be either permitted to cool in the crucible, or poured into a heated mould anointed with tallow, never with oil, or what is still better, covered with a thin coating of chalk, which is applied by laying it over with a mixture of chalk diffused in water, and then evaporating the water completely by heat. To prevent the crucible from being broken by cooling too rapidly, it should be either replaced in the furnace, to cool gradually with it, or covered with some vessel to prevent its being exposed immediately to the air.

492. Fusion is performed with the intentions,

a. Of weakening the attraction of aggregation,
1. To facilitate mechanical division;
2. To promote chemical action.

b. Of separating from each other, substances of different degrees of fusibility.

493. *Vaporization* is the conversion of a solid or fluid into vapour by the agency of caloric. Although vaporability be merely a relative term, substances are said to be permanently elastic, volatile, or fixed. The permanently elastic fluids or gases are those which cannot be condensed into a fluid or solid form by any abstraction of caloric we are capable of producing. Fixed substances, on the contrary, are those which cannot be converted into vapour, by great increase of temperature. The pressure of the atmosphere has a very considerable effect in varying the degree at which substances are converted into vapour. Some solids, unless subjected to very great pressure, are at once converted into vapour, although most of them pass through the intermediate state of fluidity.

494. Vaporization is employed,

a. To separate substances differing in volatility.

b. To promote chemical action, by disaggregating them.

495. When employed with either of these views, either

a. No regard is paid to the substances volatilized,
1. From solids, as in ustulation and charring;
2. From fluids, as in evaporation;

b. Or the substances vaporized are condensed in proper vessels,
1. In a liquid form, as in distillation,
2. In a solid form, as in sublimation;

c. Or the substances disengaged are permanently elastic, and are collected in their gaseous form, in a pneumatic apparatus.

496. *Ustulation* is almost entirely a metallurgic operation, and is employed to expel the sulphur and arsenic contained in some metallic ores. On small quantities it is performed in tests placed within a muffle. Tests are shallow vessels made of bone ashes, or baked clay. Muffles are vessels of baked clay, of a semi-cylindrical form, the flat side forming the floor, and the arched portion the roof and sides. The end and sides are perforated with holes for the free transmission of the heated air, and the open extremity is placed at the door of the furnace, for the inspection and manipulation of the process. The reverberatory furnace is commonly employed for roasting, and the heat is very gentle at first, and slowly raised to redness. The process is accelerated by exposing as large a surface of the substance to be roasted as possible, and by stirring it frequently, so as to prevent any agglutination, and to bring every part in succession to the surface.

497. *Charring* may be performed on any of the compound oxides, by subjecting them to a degree of heat sufficient to expel all their hydrogen, nitrogen, and oxygen, while the carbon, being a fixed principle, remains behind in the state of charcoal. The temperature necessary for the operation may be produced either by the combustion of other substances, or by the partial combustion of the substance to be charred. In the former case, the operation may be performed in any vessel which excludes the air while it permits the escape of the vapours formed. In the latter, the access of air must be regulated in such a manner, that it may be suppressed whenever the combustion has reached the requisite degree; for if continued to be admitted, the charcoal itself would be dissipated in the form of carbonic acid gas, and nothing would remain but the alkaline and earthy matter, which these substances always contain. When combustion is carried this length, the process is termed *incineration*. The vapours which arise in the operation of charring are sometimes condensed, as in the manufacture of tar.

498. *Evaporation* is the conversion of a fluid into vapour, by its combination with caloric. In this process, the atmosphere is not a necessary agent, but rather a hindrance, by its pressure. This forms a criterion between evaporation and spontaneous evaporation, which is merely the solution of a fluid in air.

499. It is performed in open, shallow, or hemispherical vessels of silver, tinned copper or iron, earthen ware or glass. The necessary caloric may be furnished by means of an open fire, a lamp or a furnace, and applied either directly, or by the intervention of sand, water, or vapour. The degree of heat must be regulated by the nature of the substance operated on. In general, it should not be greater than what is absolutely necessary.

500. Evaporation may be,

a. Partial:

1. From saline fluids, Concentration;
2. From viscid fluids, Inspissation.

b. Total, Exsiccation.

501. *Concentration* is employed,

a. To lessen the quantity of diluting fluids; Dephlegmation:

b. As a preliminary step to Crystallization.

502. *Inspissation* is almost confined to animal and vegetable substances; and as these are apt to be partially decomposed by heat, or to become empyreumatic, the process should always be performed, especially towards the end, in a water or vapour bath.

503. *Exsiccation* is here taken in a very limited sense; for the term is also with propriety used to express the drying of vegetables by a gentle heat, the efflorescence of salts, and the abstraction of moisture from mixtures of insoluble powders with water, by means of chalk-stones, or powdered chalk pressed into a smooth mass. At present, we limit its meaning to the total expulsion of moisture from any body by means of caloric.

504. The exsiccation of compound oxides should always be performed in the water bath.

505. Salts are deprived of their water of crystallization by exposing them to the action of heat in a glass vessel or iron ladle. Sometimes they first dissolve in their water of crystallization (or undergo what is called the *watery fusion*,) and are afterwards converted into a dry mass by its total expulsion; as in the calcination of borax or burning of alum.

506. When exsiccation is attended with a crackling noise, and the splitting of the salt, as in muriate of soda, it is termed *decrepitation*, and is performed by throwing into a heated iron vessel, small quantities of the salt at a time, covering it up, and waiting until the decrepitation be over, before a fresh quantity is thrown in.

507. Exsiccation is performed on saline bodies, to render them more acrid or pulverulent, or to prepare them for chemical operations. Animal and vegetable substances are exsiccated to give them a solid form, and to prevent their fermentation.

508. *Condensation* is the reverse of expansion, and is produced either,

a. By mechanical pressure forcing out the caloric in a sensible form, as water is squeezed out of a sponge; or,
b. By the chemical abstraction of caloric, which is followed by an approximation of the particles of the substance.

509. The latter species of condensation only is the object of our investigation at present. In this way we may be supposed to condense,

a. Substances existing naturally as gases or vapours;
b. Substances, naturally solid or fluid, converted into vapours by adventitious circumstances.

510. The former instance is almost supposititious; for we are not able, by any diminution of temperature, to reduce the permanently elastic fluids to a fluid or solid state.

511. The latter instance is always preceded by vaporization, and comprehends those operations in which the substances vaporised are condensed in proper vessels. When the product is a fluid, it is termed distillation; when solid, sublimation.

512. *Distillation* is said to be performed,

a. *Viâ humidâ*, when fluids are the subject of the operation;
b. *Viâ siccâ*, when solids are subjected to the operation, and the fluid product arises from decomposition, and a new arrangement of the constituent principles.

513. The objects of distillation are,

a. To separate more volatile fluids from less volatile fluids or solids;
b. To promote the union of different substances;
c. To generate new products by the action of fire.

514. In all distillations, the heat applied should not be

greater than what is necessary for the formation of the vapour, and even to this degree it should be gradually raised. The vessels also in which the distillation is performed should never be filled above one-half, and sometimes not above one-fourth, lest the substance contained in them should boil over.

515. As distillation is a combination of evaporation and condensation, the apparatus consists of two principal parts;

a. The vessels in which the vapours are formed;
b. The vessels in which they are condensed.

516. The vessels employed for both purposes are variously shaped, according to the manner in which the operation is conducted. The first difference depends on the direction of the vapour after its formation. It either

a. Descends; distillation *per descensum:*
b. Ascends; distillation *per ascensum:*
c. Or passes off by the side; distillation *per latus.*

517. In the distillation *per descensum*, a perforated plate, generally of tinned iron, is fixed within any convenient vessel, so as to leave a space beneath it. The subject of the operation is laid on this plate, and is covered by another, accurately fitting the vessel, and sufficiently strong to support the fuel which is burnt upon it. Thus the heat is applied from above, and the vapour is forced to descend into the inferior cavity, where it is condensed. In this way the oil of cloves is prepared, and on the same principles tar is manufactured, and mercury and zinc are separated from their ores.

518. In the distillation *per ascensum*, the vapour is allowed to arise to some height, and then is conveyed away to be condensed. The vessel most commonly employed for this purpose is the common copper-still, which consists of a body for containing the materials, and a head into which the vapour ascends. From the middle of the head a tube arises a short way, and is then reflected downwards, through which the steam passes to be condensed. Another kind of head, rising to a great height before it is reflected, is sometimes used for separating fluids, which differ little in volatility, as it was supposed that the less volatile vapours would be condensed, and fall back into the still, while only the more volatile vapours would arise to the top, so as to pass to the refrigeratory. The same object may be more conveniently attained by managing the fire with caution and address. The greater the surface exposed, and the less the height the vapours have to ascend, the more rapidly does the distillation proceed; and so well are these principles understood by the Scotch distillers, that they

do not take more than three minutes to discharge a still containing 50 gallons of fluid.

519. The condensing apparatus used with the common still is very simple. The tube in which the head terminates, is inserted into the upper end of a pipe, which is kept cool by passing through a vessel filled with water, called the Refrigeratory. This pipe is commonly made of a serpentine form: but as this renders it difficult to be cleaned, Dr Black recommends a sigmoid pipe. The refrigeratory may be furnished with a stop-cock, that when the water it contains becomes too hot, and does not condense all the vapour produced, it may be changed for cold water. From the lower end of the pipe, the product of the distillation drops into the vessel destined to receive it; and we may observe, that when any vapour issues along with it, we should either diminish the power of the fire, or change the water in the refrigeratory.

520. *Circulation* was a process formerly in use. It consisted in arranging the apparatus, so that the vapours were no sooner condensed into a fluid form, than this fluid returned back into the distilling vessels, to be again vaporized; and was effected by distilling in a glass vessel, with so long a neck that the vapours were condensed before they escaped at the upper extremity, or by inverting one matrass within another.

521. When corrosive substances are distilled *per ascensum*, the cucurbit and alembic are used; but these substances are more conveniently distilled *per latus*.

522. The distillation *per latus* is performed in a retort, or pear-shaped vessel, having the neck bent to one side. The body of a good retort is well rounded, uniform in its appearance, and of an equal thickness, and the neck is sufficiently bent to allow the vapours, when condensed, to run freely away, but not so much as to render the application of the receiver inconvenient, or to bring it too near the furnace. The passage from the body into the neck must be perfectly free and sufficiently wide, otherwise the vapours produced in the retort only circulate in its body, without passing over into the receiver. For introducing liquors into the retort without soiling its neck, which would injure the product, a bent funnel is necessary. It must be sufficiently long to introduce the liquor directly into the body of the retort; and in withdrawing it, we must keep it carefully applied to the upper part of the retort, that the drop hanging from it may not touch the inside of the neck. In some cases, where a mixture of different substances is to be distilled, it is convenient and necessary to have the whole apparatus properly adjusted before the mixture is made, and we must therefore employ a tubulated

retort, or a retort furnished with an aperture, accurately closed with a ground stopper.

523. The tubulature should be placed on the upper convex part of the retort before it bends to form the neck, so that a fluid poured through it may fall directly into the body without soiling the neck.

524. Retorts are made of various materials. Flint-glass is commonly used when the heat is not so great as to melt it. For distillations which require excessive degrees of heat, retorts of earthen ware, or coated glass retorts, are employed. Quicksilver is distilled in iron retorts.

525. The simplest condensing apparatus used with the retort is the common glass receiver; which is a vessel of a conical or globular form, having a neck sufficiently wide to admit the neck of a retort. To prevent the loss and dissipation of the vapours to be condensed, the retort and receiver may be accurately ground to each other, or secured by some proper lute. Means must also be used to prevent the receiver from being heated by the caloric evolved during the condensation of the vapours. It may either be immersed in cold water, or covered with snow or pounded ice; or a constant evaporation may be supported from its surface, by covering it with a cloth, kept moist by means of the descent of water, from a vessel placed above it, through minute syphons or spongy worsted threads. But as, during the process of distillation, permanently elastic fluids are often produced, which would endanger the breaking of the vessels, these are permitted to escape, either through a tubulature, or hole in the side of the receiver, or rather through a hole made in the luting. Receivers having a spout issuing from their side, are used when we wish to keep separate the products obtained at different periods of any distillation. For condensing very volatile vapours, a series of receivers, communicating with each other, termed Adopters, were formerly used; but these are now entirely superseded by Woulfe's apparatus.

526. This apparatus consists of a tubulated retort, adapted to a tubulated receiver. With the tubulature of the receiver a three-necked bottle is connected by means of a bent tube, the further extremity of which is immersed, one or more inches, in some fluid contained in the bottle. A series of two or three similar bottles are connected with this first bottle in the same way. In the middle tubulature of each bottle, a glass tube is fixed, having its lower extremity immersed about a quarter of an inch in the fluid. The height of the tube above the surface of the fluid must be greater than the sum of the columns of fluid standing over the farther extremities of the

connecting tubes, in all the bottles or vessels more remote from the retort. Tubes so adjusted are termed Tubes of safety, for they prevent that reflux of fluid from the more remote into the nearer bottles, and into the receiver itself, which would otherwise inevitably happen, on any condensation of vapour taking place in the retort, receiver, or nearer bottles. Different contrivances for the same purpose have been described by Messrs Welter and Burkitt; and a very ingenious mode of connecting the vessels without lute has been invented by Citizen Girard, but they would not be easily understood without plates. The further tubulature of the last bottle is commonly connected with a pneumatic apparatus, by means of a bent tube. When the whole is properly adjusted, air blown into the retort should pass through the receiver, rise in bubbles through the fluids contained in each of the bottles, and at last escape by the bent tube. In the receiver, those products of distillation are collected, which are condensable by cold alone. The first bottle is commonly filled with water, and the others with alkaline solutions, or other active fluids; and as the permanently elastic fluids produced are successively subjected to the action of all these, only those gases will escape by the bent tube which are not absorbable by any of them.

PNEUMATIC APPARATUS.

527. The great importance of the elastic fluids in modern chemistry has rendered an acquaintance with the means of collecting and preserving them indispensable.

528. When a gas is produced by any means, it may be received either,

a. Into vessels absolutely empty; or

b. Into vessels filled with some fluid, on which it exerts no action.

529. The first mode of collecting gases may be practised by means of a bladder, moistened sufficiently to make it perfectly pliable, and then compressed so as to empty it entirely. In this state it may be easily filled with any gas. An oiled silk bag will answer the same purpose, and is more convenient in some respects, as it may be made of any size or form.

530. Glass or metallic vessels, such as balloons, may also be emptied for the purpose of receiving gases, by fitting them with a stop-cock, and exhausting the air from them by means of an air-pump.

531 But the second mode of collecting gases is the most convenient and common.

532. The vessels may be filled either,

a. With a fluid lighter; or

b. Heavier than the gas to be received into it.

533. The former method is seldom employed; but if we conduct a stream of any gas heavier than atmospheric air, such as carbonic acid gas, muriatic acid gas, &c. to the bottom of any vessel, it will gradually displace the air, and fill the vessel.

534. On the contrary, a gas lighter than the atmospheric air, such as hydrogen, may be collected in an inverted vessel, by conducting a stream of it to the top.

535. But gases are most commonly collected by conducting the stream of gas into an inverted glass jar, or any other vessel filled with water or mercury. The gas ascends to the upper part of the vessel, and displaces the fluid. In this way gas may be kept a very long time, provided a small quantity of the fluid be left in the vessels, which prevents both the escape of the gas, and the admission of atmospheric air.

536. The vessels may be of various shapes; but the most commonly employed are cylindrical. They may be either open only at one extremity, or furnished at the other with a stop-cock.

537. The manner of filling these vessels with fluid is to immerse them completely in it, with the open extremity directed a little upwards, so that the whole air may escape from them, and then inverting them with their mouths downwards.

538. For filling them with convenience, a trough or cistern is commonly used. This either should be hollowed out of a solid block of wood or marble; or, if it be constructed of wood, it should be well painted, or lined with lead or tinned copper. Its size may vary very much; but it should contain a sufficient depth of fluid to cover the largest transverse diameter of the vessels to be filled in it. At one end or side, there should be a shelf for holding the vessels after they are filled. This shelf should be placed about an inch and a half below the surface of the fluid, and should be perforated with several holes, forming the apices of corresponding conical excavations on the lower side, through which, as through inverted funnels, gaseous fluids may be more easily introduced into the vessels placed over them. In general, the vessels used with a mercurial apparatus should be stronger and smaller than those for a water-cistern.

539. We should also have a variety of glass and elastic tubes for conveying the gases from the vessels in which they are formed to the funnels under the shelf.

540. *Rectification* is the repeated distillation of any fluid. When distillation renders the fluid stronger, or abstracts water from it, it is termed *Dephlegmation.* When a fluid is distilled off from any substance, it is called *Abstraction;* and if the product be redistilled from the same substance, or a fresh quantity of the substance, it is denominated *Cohobation.*

541. *Sublimation* differs from distillation only in the form of the product. When it is compact, it is termed a Sublimate; when loose and spongy, it formerly had the improper appellation of Flowers. Sublimation is sometimes performed in a crucible, and the vapours are condensed in a paper cone, or in another crucible inverted over it; sometimes in the lower part of a glass flask, cucurbit, or phial, and the condensation is effected in the upper part or capital, and sometimes in a retort with a very short and wide neck, to which a conical receiver is fitted. The heat is most commonly applied through the medium of a sand-bath; and the degree of heat, and the depth to which the vessel is inserted in it, are regulated by the nature of the sublimation.

542. *Congelation* is the reduction of a fluid into a solid form, in consequence of the abstraction of caloric. The means employed for abstracting caloric are the evaporation of volatile fluids, the solution of solids, and the contact of cold bodies.

543. *Coagulation* is the conversion of a fluid into a solid of greater or less consistence, merely in consequence of a new arrangement of its particles, as during the process there is no separation of caloric or any other substance. The means of producing coagulation are, increase of temperature, and the addition of certain substances, as acids and runnets.

COMBINATION.

544. Chemical combination is the intimate union of the particles of at least two heterogeneous bodies. It is the effect resulting from the exertion of the attraction of affinity, and is therefore subjected to all the laws of affinity.

545. To produce the chemical union of any bodies it is necessary,

1. That they possess affinity for each other;
2. That their particles come into actual contact;
3. That the strength of the affinity be greater than any counteracting causes which may be present.

546. The principal counteracting causes are,

1. The attraction of aggregation;
2. Affinities for other substances.

547. The means to be employed for overcoming the action of other affinities will be treated of under Decomposition.

548. The attraction of aggregation is overcome by means of

1. Mechanical division.
2. The action of caloric.

549. Combination is facilitated by increasing the points of actual contact.

1. By mechanical agitation;
2. By condensation; compression.

550. The processes employed for producing combination may be considered,

1. With regard to the nature of the substances combined; and,
2. To the nature of the compound produced.

Gases,

1. Combine with gases;
2. Dissolve fluids or solids;
3. Or are absorbed by them.

Fluids,

1. Are dissolved in gases;
2. Or absorb them;
3. Combine with fluids;
4. And dissolve solids;
5. Or are rendered solid by them.

Solids,

1. Are dissolved in fluids and in gases; or,
2. Absorb gases;
3. And solidify fluids.

551. The combination of gases with each other, in some instances, takes place when simply mixed together: thus nitrous and oxygen gases combine as soon as they come into contact; in other instances, it is necessary to elevate their temperature to a degree sufficient for their inflammation, either by means of the electric spark, or the contact of an ignited body, as in the combination of oxygen gas with hydrogen or nitrogen gas.

552. When gases combine with each other, there is always a considerable diminution of bulk, and not unfrequently they are condensed into a liquid or solid form. Hydrogen and oxygen gases form water: muriatic acid and ammonia gases form solid muriate of ammonia. But when the combination is effected by ignition, a violent expansion, which endangers the bursting of the vessels, previously takes place, in consequence of the increase of temperature.

553. *Solution* is the diminution of aggregation in any solid or fluid substance, in consequence of its entering into chemical combination. The substance, whether solid or fluid, whose aggregation is lessened, is termed the *Solvend*; and the substance, by whose agency the solution is effected, is often called the *Menstruum* or *Solvent*.

554. Solution is said to be performed *via humida*, when the natural form of the solvent is fluid; but when the agency of heat is necessary to give the solvent its fluid form, the solution is said to be performed *via sicca*.

555. The dissolving power of each menstruum is limited, and is determinate with regard to each solvend. The solubility of bodies is also limited and determinate with regard to each menstruum.

556. When any menstruum has dissolved the greatest possible quantity of any solvend, it is said to be saturated with it. But in some cases, although saturated with one substance, it is still capable of dissolving others. Thus a saturated solution of muriate of soda will dissolve a certain quantity of nitrate of potass, and after that a portion of muriate of ammonia.

557. The dissolving power of solvents, and consequently the solubility of solvends, are generally increased by increase of temperature; and conversely, this power is diminished by diminution of temperature; so that, from a saturated solution, a separation of a portion of the solvend generally takes place on any reduction of temperature. This property becomes extremely useful in many chemical operations, especially in crystallization.

558. Particular terms have been applied to particular cases of solution.

559. The solution of a fluid in the atmosphere is termed *spontaneous evaporation*. It is promoted by exposing a large surface, by frequently renewing the air in contact with the surface, and by increase of temperature.

560. Some solids have so strong an affinity for water, that they attract it from the atmosphere in sufficient quantity to dissolve them. These are said to *deliquesce*. Others, on the

contrary, retain their water of crystallization with so weak a force, that the atmosphere attracts it from them, so that they crumble into powder. These are said to *effloresce.* Both operations are promoted by exposing large surfaces, and by a current of air; but the latter is facilitated by a warm dry air, and the former by a cold humid atmosphere.

561. Solution is also employed to separate substances (for example, saline bodies,) which are soluble in the menstruum, from others which are not. When our object is to obtain the soluble substance in a state of purity, the operation is termed *lixiviation.* In this as small a quantity of the menstruum as is possible is used. When, however, solution is employed to free an insoluble substance from soluble impurities, it is termed *edulcoration*, which is best performed by using a very large quantity of the menstruum.

562. Organic products being generally composed of heterogeneous substances, are only partially soluble in the different menstrua. To the solution of any of these substances, while the others remain undissolved, the term *extraction* is applied; and when, by evaporation, the substance extracted is reduced to a solid form, it is termed an Extract, which is hard or soft, watery or spiritous, according to the degree of consistency it acquires, and the nature of the menstruum employed.

563. *Infusion* is employed to extract the virtues of aromatic and volatile substances, which would be dissipated by decoction, and destroyed by maceration, and to separate substances of easy solution from others which are less soluble. The process consists in pouring upon the substance to be infused, placed in a proper vessel, the menstruum, either hot or cold, according to the direction, covering it up, agitating it frequently, and after a due time straining or decanting off the liquor, which is then termed the Infusion.

564. *Maceration* differs from infusion, it being continued for a longer time, and can only be employed for substances which do not easily ferment or spoil.

565. *Digestion*, on the other hand, differs from maceration only in the activity of the menstruum being promoted by a gentle degree of heat. It is commonly performed in a glass matrass, which should only be filled one-third, and covered with a piece of wet bladder, pierced with one or more small holes, so that the evaporation of the menstruum may be prevented as much as possible, without risk of bursting the vessel. The vessel may be heated, either by means of the sun's rays, of a common fire, or of the sand-bath; and when the last is employed, the vessel should not be sunk deeper in the

sand than the portion that is filled. Sometimes, when the menstruum employed is valuable, a distilling apparatus is used to prevent any waste of it. At other times, a blind capital is luted on the matrass, or a smaller matrass is inverted within a larger one; and as the vapour which arises is condensed in it, and runs back into the larger, the process in this form has got the name of *Circulation.*

566. *Decoction* is performed by subjecting the substances operated on to a degree of heat, which is sufficient to convert the menstruum into vapour, and can only be employed with advantage for extracting principles which are not volatile, and from substances whose texture is so dense and compact as to resist the less active methods of solution. When the menstruum is valuable, that portion of it which is converted into vapour is generally saved by condensing it in a distilling apparatus.

567. Solutions in alcohol are termed Tinctures, and in vinegar or wine, Medicated vinegars or wines. The solution of metals in mercury is termed Amalgamation. The combinations of other metals with each other form Alloys.

568. *Absorption* is the condensation of a gas into a fluid or solid form, in consequence of its combination with a fluid or solid. It is facilitated by increase of surface and agitation; and the power of absorption in fluids is much increased by compression and diminution of temperature, although in every instance it be limited and determinate. Dr Nooth invented an ingenious apparatus for combining gases with fluids; and Messrs Schweppe, Henry, Paul, and Cuthbertson, have very advantageously employed compression.

569. *Consolidation.* Fluids often become solid by entering into combination with solids; and this change is always accompanied by considerable increase of temperature, as in the slaking of lime.

DECOMPOSITION.

570. *Decomposition* is the separation of bodies which were chemically combined.

571. It can only be effected by the agency of substances possessing a stronger affinity for one or more of the constituents of the compound, than these possess for each other.

572. Decomposition has acquired various appellations, according to the phenomena which accompany it.

573. *Dissolution* differs from solution in being accompanied by the decomposition, or a change in the nature of the substance dissolved. Thus, we correctly say, a solution of lime

in muriatic acid, and a dissolution of chalk in muriatic acid.

474. Sometimes a gas is separated during the action of bodies on each other. When this escapes with considerable violence and agitation of the fluid it is termed *effervescence.* The gas is very frequently allowed to escape into the atmosphere, but at other times is either collected in a pneumatic apparatus, or made to enter into some new combination.—The vessels in which an effervescing mixture is made, should be high and sufficiently large, to prevent any loss of the materials from their running over; and in some cases the mixture must be made slowly and gradually.

575. *Precipitation* is the reverse of solution. It comprehends all those processes in which a solid is obtained by the decomposition of a solution. The substance separated is termed a Precipitate, if it sink to the bottom of the fluid; or a Cream, if it swim above it. Precipitation, like solution, is performed either *via humida*, or *via sicca.*

576. The objects of precipitation are,

1. The separation of substances from solutions in which they are contained;
2. The purification of solutions from precipitable impurities;
3. The formation of new combinations.

577. Precipitation is effected,

1. By lessening the quantity of the solvent by evaporation;
2. By diminishing its solvent power, as by reduction of temperature, or dilution;
3. Or by the addition of some chemical agent, which from its more powerful affinities,
   a. Either combines with the solvent, and precipitates the solvend,
   b. Or forms itself an insoluble compound with some constituent of the solution.

578. The two first means of precipitation have been already noticed. Indeed they are rarely considered as instances of precipitation, as the effect is gradual, and the precipitated matter most commonly assumes determinate figures.

579. In performing it in the last manner, we may observe the following rules:

1. The solution and precipitant must possess the requisite degree of purity.
2. The solution should be perfectly saturated, to avoid unnecessary consumption of the solvent or precipitant.
3. The one is to be added slowly and gradually to the other.

4. After each addition, they are to be thoroughly mixed by agitation.
5. We must allow the mixture to settle, after we think that enough of the precipitant has been added, and try a little of the clear solution, by adding to it some of the precipitant: if any precipitation takes place, we have not added enough of the precipitant. This precaution is necessary, not only to avoid loss, but, in many instances, the precipitant, if added in excess, redissolves, or combines with the precipitate.

580. After the precipitation is completed, the precipitate is to be separated from the supernatant fluid by some of the means already noticed.

581. When the precipitate is the chief object of our process, and when it is not soluble in water, it is often advisable to dilute, to a considerable degree, both the solution and precipitant, before performing the operation. When it is only difficultly soluble, we must content ourselves with washing the precipitate, after it is separated by filtration. In some cases, the separation of the precipitate is much assisted by a gentle heat.

582. *Crystallization* is a species of precipitation, in which the particles of the solvend, on separating from the solution, assume certain determinate forms.

583. The conditions necessary for crystallization are,

1. That the integrant particles have a tendency to arrange themselves in a determinate manner when acted on by the attraction of aggregation;
2. That they be disaggregated, at least so far as to possess sufficient mobility to assume their peculiar arrangement;
3. That the causes disaggregating them be slowly and gradually removed.

584. Notwithstanding the immense variety in the forms of crystals, M. Hauy has rendered it probable that there are only three forms of the integrant particles:

1. The parallelopiped.
2. The triangular prism.
3. The tetrahedron.

585. But as these particles may unite in different ways, either by their faces or edges, they will compose crystals of various forms.

586. The primitive forms have been reduced to six.

1. The parallelopiped.
2. The regular tetrahedron.
3. The octohedron, with triangular faces.
4. The six-sided prism.
5. The dodecahedron terminated by rhombs.
6. The dodecahedron with isosceles triangular faces.

587. Almost all substances, on crystallizing, retain a portion of water combined with them, which is essential to their existence as crystals, and is therefore denominated water of crystallization. Its quantity varies very much in different crystallized substances.

588. The means by which the particles of bodies are disaggregated, so as to admit of crystallization, are solution, fusion, vaporization, or mechanical division and suspension in a fluid medium.

589. The means by which the disaggregating causes are removed, are, evaporation, reduction of temperature, and rest.

590. When bodies are merely suspended in a state of extreme mechanical division, nothing but rest is necessary for their crystallization.

591. When they are disaggregated by fusion or vaporization, the regularity of their crystals depends on the slowness with which their temperature is reduced; for if cooled too quickly, their particles have not time to arrange themselves, and are converted at once into a confused or unvaried solid mass. Thus glass, which, when cooled quickly, is so perfectly uniform in its appearance, when cooled slowly, has a crystalline texture. But in order to obtain crystals by means of fusion, it is often necessary, after the substance has begun to crystallize, to remove the part which remains fluid; for otherwise it would fill up the interstices among the crystals first formed, and give the whole the appearance of one solid mass. Thus, after a crust has formed on the top of melted sulphur, by drawing out the still fluid part, we obtain regular crystals.

592. The means by which bodies, which have been disaggregated by solution, are made to crystallize more regularly, vary according to the habitudes of the bodies with their solvents and caloric.

593. Some saline substances are much more soluble in hot than in cold water; therefore, a boiling saturated solution of any of these will deposite, on cooling, the excess of salt, which it is unable to dissolve when cold. These salts commonly contain much water of crystallization.

594. Other salts are scarcely, if at all, more soluble in hot than in cold water; and therefore their solutions must be evaporated, either by heat, or spontaneously. These salts commonly contain little water of crystallization.

595. The beauty and size of the crystals depend upon the purity of the solution, its quantity, and the mode of conducting the evaporation and cooling.

596. When the salt is not more soluble in hot than in cold water, by means of gentle evaporation, a succession of pellicles is formed on the top of the solution, which either are removed, or permitted to sink to the bottom by their own weight; and the evaporation is continued until the crystallization be completed.

597. But when the salt is capable of crystallizing on cooling, the evaporation is only continued until a drop of the solution, placed upon some cold body, shews a disposition to crystallize, or at farthest only until the first appearance of a pellicle. The solution is then covered up, and set aside to cool; and the more slowly it cools, the more regular are the crystals. The mother water, or solution which remains after the crystals are formed, may be repeatedly treated in the same way as long as it is capable of furnishing any more salt.

598. When very large and beautiful crystals are wanted, they may be obtained by laying well-formed crystals in a saturated solution of the same salt, and turning them every day. In this way their size may be considerably increased, though not without limitation; for after a certain time, they grow smaller instead of larger.

599. Crystallization is employed,

1. To obtain crystallizable substances in a state of purity;
2. To separate them from each other, by taking advantage of their different solubility at different temperatures.

OXYGENIZEMENT.

600. The combination of oxygen is the object of many chemical and pharmaceutical processes.

601. With regard to the manner of combination, the oxygenizement may take place, either,

a. Without the production of heat and light, to express which there is no other than the generic term *oxygenizement*; or,

b. With the production of heat and light; *combustion*.

1. In substances which remain fixed at the tempe-

rature necessary for their combustion, there is no other more specific term;

2. In substances which exist as gases, or are previously reduced to the state of vapour by the temperature necessary, it is termed *inflammation;* and if it proceed with very great violence and rapidity, *deflagration.*

602. Combustion and inflammation have been already described.

603. *Deflagration*, from its violence, must always be performed with caution. The common mode of conducting this process is, to introduce the substances to be deflagrated together into any convenient vessel, commonly an iron pot, or crucible, heated to redness. But to obviate any inconvenience, and to insure the success of the process, they are previously made perfectly dry, reduced to powder, and thoroughly mixed together. The compound is then deflagrated gradually, generally by spoonfuls; but we must take care always to examine the spoon, lest a spark should adhere to it, which might set fire to the whole mass. During the process, the portion introduced should be frequently stirred.

604. The oxygen necessary for the process of oxygenation may be derived from the decomposition,

a. Of oxygen gas, or atmospheric air;
b. Of oxides, particularly water;
c. Of acids and their combinations.

605. The different modes of oxygenizement are intended, either,

a. To produce heat and light;
b. To obtain an oxygenized product;
    1. An oxide, when the process may be termed *Oxidizement.*
    2. An acid, *Acidification.*
c. To remove an oxygenizable substance.

606. Hydrogen, carbon, and nitrogen, are never, unless for experiment, oxygenized as simple substances.

607. Sulphur is converted into sulphuric acid by burning it in leaden chambers, or by deflagating it with nitrate of potass: and phosphorus is acidified by inflammation in the atmosphere.

608. Of all the simple oxygenizable substances, the metals are most frequently combined with oxygen; and, as in conse-

quence of this combination, they lose their metallic appearance, they were formerly said to be calcined or corroded.

609. Metals differ very much in the facility with which they are oxygenized by the contact of oxygen gas. For some, as iron and manganese, the ordinary temperature of the atmosphere is necessary; but others, as potassium and sodium, are oxygenized even by the contact of ice: while others, as gold, and platinum, scarcely undergo any change in the most violent heat. Upon these the operation is performed by heating them to the requisite temperature, and exposing them to the action of the air: and on the fusible metals it is promoted by stirring them when melted.

610. Metals also differ in the mode of their action upon water. They are either capable of decomposing water,

a. At every temperature, as potassium and sodium.
b. At ordinary temperatures, as iron, zinc, manganese, &c.
c. At elevated temperatures, as antimony and tin; or
d. When acted upon at the same time by an acid or an alkali, as copper, lead, bismuth; or, lastly,
e. They are incapable of decomposing it, as gold, silver, mercury, platinum.

611. The oxygenizement of metals by water is promoted by the action of air. Iron, for example, is more quickly rusted by being merely moistened with water, than when totally immersed in water.

612. But the acids are the most powerful agents in oxygenizing metals. They act, in two ways, either,

1. By enabling them to decompose water.
2. By being decomposed themselves.

613. The metals are susceptible of different degrees of oxygenizement, some of them even of acidification, aud, in general, they are more oxygenized according to the rapidity of the process. When proceeding too slowly, it may be accelerated by heat; when too violent, it must be checked by diminution of temperature, as by plunging the vessel in which the operation is performed into cold water.

614. When the degree of oxygenizement is not very great the oxide formed generally enters into combination with the acid employed, and forms a metallic salt; but when carried to its highest degree, the oxide is often insoluble.

DISOXYGENIZEMENT OF METALLIC OXIDES AND ACIDS.

615. This process was formerly termed *reduction*, from its restoring the metals to their metallic splendour, and is per-

formed by causing some body to act upon them, which has a greater affinity for oxygen than they have. The different metals themselves vary very much in the degree of this affinity, so that they are reduced with very different degrees of facility. Gold, silver, platinum, and mercury, are reduced by merely exposing them to a sufficient degree of heat in close vessels. The oxygen at this temperature has a greater affinity for caloric than for the metals, and is therefore driven off in the form of very pure oxygen gas.

616. Some other metallic oxides which resist the simple action of heat, may be reduced by melting them in contact with charcoal, or substances which may be charred, such as oil, fat, resin, pitch, &c. Besides the charcoal, different saline fluxes are also added to facilitate the fusion of the oxide.

617. The oxide to be reduced is mixed with a sufficient quantity of any of these substances, and placed in the bottom of a crucible, which is afterwards filled up with charcoal powder, to prevent entirely the access of the air, and exposed for a length of time to a sufficiently high temperature, when a button of the metal will commonly be found in the bottom of the crucible. Upon the volatile metals, such as arsenic and zinc, this operation must be performed in a distilling or subliming apparatus. Some metallic oxides, such as those of platinum, columbium, &c. cannot be reduced, from our being unable to produce a degree of heat sufficient to melt them.

618. But galvanism is by far the most powerful disoxygenizing process. By means of it the metallic bases of the alkalies and earths have been discovered.

619. Metals may be also obtained from the metallic salts, by inserting in a solution of these a plate of another metal, possessing a stronger affinity for oxygen than for the acid. Thus copper is precipitated by iron, and arsenic by zinc. We must only take care that the two metals have no remarkable affinity for each other, as in that case an alloy is commonly produced. For example, when mercury is placed in a solution of silver, a crystallized amalgam of silver is obtained, formerly called the Arbor Dianæ.

620. The compound oxides, (vegetable and animal substances,) may be further oxygenized, by treating them with nitric acid. In this way various oxides and acids are formed, according to the nature of the oxide operated on, the quantity of the acid, and the mode of conducting the process.

621. These substances also undergo changes by gradually combining with the oxygen of the atmosphere. In some cases, this combination is attended with remarkable phenomena, which have been classed under the term *fermentation*.

622. There are several species of fermentation, which have been named from the products they afford,

1. The saccharine, which produces sugar.
2. The vinous, which produces wine, beer, and similar fluids.
3. The panary, which produces bread.
4. The acetous, which produces vinegar.
5. The putrefactive, which produces ammonia.

623. The same substances are sometimes capable of undergoing the first, second, fourth, and fifth ; or third, fourth, and fifth, successively, but never in a retrograde order.

624. The conditions necessary for all of them are,

1. The presence of a sufficient quantity of fermentable matter ;
2. The presence of a certain proportion of water ;
3. The contact of atmospheric air ; and,
4. A certain temperature.

625. *The saccharine fermentation.*—The seeds of barley, when moistened with a certain quantity of water, and exposed to the contact of the atmospheric air, at a temperature of not less than 50°, swell, and shew marks of incipient vegetation, by pushing forth the radicle. If at this period the fermentation be checked, by exposing them to a considerable degree of heat and drying them thoroughly, the insipid amylaceous matter, of which the seeds principally consisted, will be found to be changed in part into a sweet saccharine substance. The oxygen of the air, in contact with the seeds, is at the same time converted into carbonic acid gas, by combining with part of the carbon of the seeds ; and there is a considerable increase of temperature in the fermenting mass, even to such a degree as sometimes to set it on fire. Similar phenomena occur in the maturation of fruits ; in the cookery of some roots and fruits, and during the heating of hay, when put up too wet.

626. *The vinous fermentation.*—The conditions necessary for the vinous fermentation, are, the presence of proper proportions of sugar, acid, extract, and water, and a temperature of about 70°. When these circumstances exist, an intestine motion commences in the fluid ; it becomes thick and muddy, its temperature increases, and carbonic acid gas is evolved. After a time the fermentation ceases, the feces rise to the top, or subside to the bottom, the liquor becomes clear, it has lost its saccharine taste, and assumed a new one, and its specific gravity is diminished. If the fermentation has been com-

plete, the sugar is entirely decomposed, and the fermented liquor consists of a large proportion of water, of alcohol, of malic acid, of extract, of essential oil, and colouring matter. The substances most commonly subjected to this fermentation are must, which is the expressed juice of the grape, and which produces the best wines; the juice of the currant and gooseberry, which, with the addition of sugar, form our home-made wines; the juices of the apple and pear, which give cyder and perry; and an infusion of malt, which, when fermented with yeast, forms beer. The briskness and sparkling of some of these liquors depend on their being put into close vessels before the fermentation is completed, by which means a portion of carbonic acid gas is retained.

627. *The acetous fermentation.*—All vinous liquors are susceptible of the acetous fermentation, provided they be exposed to the action of the atmosphere, in a temperature not less than 70°. An intestine motion and hissing noise sensibly takes place in the fluid; it becomes turbid, with filaments floating in it, and its temperature increases; it exhales a pungent acid smell, without any disengagement of carbonic acid gas. Gradually these phenomena cease; the temperature decreases, the motion subsides, and the liquor becomes clear, having deposited a sediment and red glairy matter, which adheres to the sides of the vessel. During this process, the alcohol and malic acid disappear entirely, oxygen is absorbed, and acetous acid formed.

628. *The panary and colouring fermentation.*—is less understood than those already described. A paste of wheat-flour and water, exposed to a temperature of 65°, swells, emits a small quantity of gas, and acquires new properties. The gluten disappears, and the paste acquires a sour disagreeable taste. If a just proportion of this fermented paste or leaven, or, what is still better, if some barm, be formed into a paste with wheat flour and water, the same fermentation is excited, without the disagreeable taste being produced; the gas evolved is prevented from escaping by the viscidity of the paste, which therefore swells, and if baked, forms light spongy bread.

629. *The putrefactive fermentation.*—Although vegetable substances, when they are destroyed by spontaneous decomposition, are said to putrefy, we shall consider this fermentation as belonging exclusively to animal substances, or those which contain nitrogen as an elementary principle. The essential conditions of putrefaction are humidity, and a temperature between 45° and 110°. The presence of air, the diminution of pressure, and the addition of ferments are not essential, but

accelerate its progress. The smell is at first vapid and disagreeable, but afterwards insupportably fetid, although the fetor, for a time, is somewhat diminished by the mixture of an ammoniacal odour. Liquids become turbid and flocculent. Soft substances melt down into a gelatinous mass, in which there is a kind of gentle motion and swelling up, from the slow and scanty formation of elastic fluids. Solids, beside the general softening, exude a serosity of various colours, and by degrees the whole mass dissolves, the swelling ceases, the matter settles, and its colour deepens; at last its odour becomes somewhat aromatic, its elements are finally dissipated, and there remains only a kind of fat, viscid, and still fetid mould. The products of putrefaction are carburetted, sulphuretted, and phosphuretted hydrogen gases, water, ammonia, azote, and carbonic acid. These are all dissipated in the form of gas or vapour. When in contact with air, oxygen is absorbed. Acetic acid, a fatty matter, a soap composed of this fat and ammonia, and often the nitric acid, fixed by a salifiable base, are also produced; and the ultimate remains, besides salts, composed of acid and earths, contain for a long time a portion of fat charry matter.