

LONDON DISPENSATORY.

PART I.

ELEMENTS OF PHARMACY.

PHARMACY is that branch of the science of chemistry which relates to the combination and mixture of different substances for the purposes of medicine.

Its practice presupposes a knowledge of the ultimate principles of the substances employed in its operations, and of their chemical agencies; and hence, of the general doctrines of Chemical Science. The elements, therefore, of Pharmacy, properly speaking, are those of Chemistry; and without a knowledge of these, it cannot be either theoretically understood, or advantageously practised as an art.

As, however, it would be impossible in this place to give more than an outline or epitome of the elements of Chemistry, and as the second part of this work is intended to contain the analysis as well as the history and uses of the different articles of the *Materia Medica* which constitute the subjects of Pharmacy, I shall confine the term Elements of Pharmacy to comprehend those general principles of chemical action which enable us to reason on, and perceive the proximate causes of the results of pharmaceutical combinations; and to the explanation of the operations of Pharmacy, with a description of the apparatus.

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SECTION I.

THE agents which more generally influence chemical, and thence pharmaceutical combinations, are *Attraction* and *Repulsion*.

I. ATTRACTION.

ATTRACTION is the term employed to denote that force which causes bodies to approach towards each other, and which preserves them in a state of union after they come into contact. We are ignorant of the cause of this force, but some of the laws respecting it are sufficiently evident; and from observing the different phenomena to which these give rise, we are inclined to believe that there are different species of attractions, although, perhaps, the difference is more in degree than in kind.

When this force is exerted on masses of matter, at sensible

distances, and in the direct ratio of the quantity of matter, and the inverse one of the square of the distance, it is named *gravitation*: but when its operation is confined to the minute atoms of bodies, and is exerted only when these are near to each other, or in apparent contact, it is denominated *contiguous attraction*. The former preserves the planets in their orbits, and sustains in their places all the parts of the magnificent frame of the universe: the second is the cause of the regular figures of natural bodies, and of the various combinations of matter, which take place in and on the surface of our globe. It is this variety that we are here to examine.

CONTIGUOUS ATTRACTION, operating on particles of the same kind, forms an aggregate or mass; and hence, the power in this instance is named the *attraction of aggregation* or *cohesion*: but acting on dissimilar particles, and producing bodies possessed of new properties, different from those of their components, it constitutes *chemical attraction*, or *affinity*.

a. OF COHESION.

The attraction of *cohesion* is that power which retains together the particles of bodies at insensible distances. According to the degree of force which it exerts, substances assume the solid, the fluid, or the aëriform state. 1. In solid bodies this force is sufficiently powerful to prevent their component particles from being moved with regard to each other, except in a very small degree; and to oppose a considerable resistance to any mechanical power applied to separate them. In the same kinds of bodies, all the circumstances being equal, it is always the same; but in dissimilar bodies it is exceedingly various: from which, and the peculiar arrangement of the particles, arise the different qualities of solids, denominated hardness, softness, malleability, ductility, and elasticity.

The attraction of cohesion in solids is exerted at insensible distances only, and may be weakened or altogether overcome by caloric, or that matter which produces the sensation of heat. If a piece of ice, for example, be brought near a fire, the cohesion of its particles is weakened as the caloric flows into it, till it is changed from the solid state to the fluid, or water; and by continuing and increasing the heat, the particles are still further separated from each other, until the fluid passes into the gaseous form, or becomes steam. This power is also weakened by chemical affinity; as when a solid body is put into a fluid, the affinity between the particles of the fluid and those of the solid is often sufficient to overcome the aggregation of the solid; and its detached particles being uniformly diffused through the fluid, now form a part of it, without altering either its fluidity or transparency. This constitutes the ordinary chemical or pharmaceutical process of *solution*, which is

always favoured by the application of heat, owing to the assistance it affords in overcoming the cohesive attraction, as has been already noticed.

2. In *liquid* bodies this force also operates, but in a less degree than in solids, their particles being at a greater relative distance, and moveable with regard to each other by a very small force; but as their mobility does not change their relative distances, they remain within the sphere of this attraction, and are kept together. The exertion of this power varies in different liquids: it is greater in mercury than in water, and in this than in alcohol. It offers, however, scarcely any resistance to the combination of fluids with other bodies: and hence, the mutual affinity of two bodies is always favoured, when one of them is in the liquid state.

3. This attraction is not exerted over *aëriform* substances; for while these remain at the temperature necessary for the preservation of their aërial state, their particles mutually repel each other, and would recede to an indefinite distance, were they not prevented by the pressure of the surrounding bodies.

One of the most important results of this variety of contiguous attraction, in a pharmaceutical point of view, is the formation of crystals, or the regular and determinate figures assumed by many solids, when nothing opposes the union of their particles according to the laws of aggregation.

The process of crystallization, however, does not take place, unless the particles of the solid become moveable; and hence, in order to obtain any body in a crystalline state, it must first be rendered fluid, either by solution in a liquid, or fusion by heat.

The crystallization of salts is usually effected in the first method. When a salt is much more soluble in hot water than in cold, as is the case, for example, with sulphate of soda, nothing more is required for its crystallization, than to saturate boiling water with it, and set the solution aside to cool. As the caloric is dissipated, the saline particles gradually approach each other, and uniting, form solids of that regular shape which characterizes the crystals of this peculiar salt. But when the salt is almost equally soluble in hot and in cold water, as muriate of soda for instance, its crystallization can only be effected by withdrawing by evaporation a part of the fluid; and the more slowly this takes place, the mutual attraction of the particles is more regularly effected, and the more regular is the shape of the crystals which are obtained. In both cases, however, the affinity of the saline particles at length ceases to act, while the fluid still retains as much saline matter as it can hold dissolved at the temperature of the atmosphere, or is a saturated solution; but, by a further evaporation, it will again yield crystals.

By *fusion*, bodies which are not soluble in water, as glass, sulphur, &c. are enabled to assume the crystalline form. In this case the body is, as it were, dissolved in caloric; and the particles being separated from each other, these, when the cooling is gradual, assume, in aggregating, the regular arrangements which take place in crystallization. This mode of crystallizing substances is never used for pharmaceutical purposes.

Crystallization is promoted or retarded by various circumstances, to be afterwards noticed. (See *Section iii.*) Its theory is still obscure; but some light has been thrown upon it by the experiments of Häüy. He found that crystals may be mechanically divided, and reduced to certain primitive forms, which are always the same in the same kind of substances, and depend upon the figure and the mode of combination of the integrant particles composing the crystals. The varieties of figure of these particles, notwithstanding the great diversity of crystalline forms, are reducible to three: namely, 1. the parallelopiped, the faces of which are six, and parallel two and two; 2. the triangular prism; and 3. the tetrahedron, or four-sided pyramid: and these particles, therefore, according to the mode in which they unite, which may be either by their faces or their edges, form primitive crystals, which are the nuclei of the secondary crystals. The forms of primitive crystals may be reduced to the following six: 1. the parallelopiped, including the cube, the rhomboid, and all solids terminated by six faces, parallel two and two; 2. the regular tetrahedron; 3. the octahedron with triangular faces; 4. the six-sided prism; 5. the dodecahedron, terminated by rhombs; and 6. the dodecahedron, with isosceles triangular faces. The variations of the forms of secondary crystals are considerable in the same salt, and depend, in general, either on variations in the proportions of the ingredients which compose the integrant particles, or on the properties of the solvent in which the crystals are formed: thus alum crystallizes in octahedrons, but the addition of a little alumina produces cubes; and an excess of this earth prevents crystallization altogether: thus also, muriate of soda, which crystallizes in cubes, when dissolved in water, assumes the regular octahedral form when it is crystallized in urine. Independent, however, of these causes, a variety of secondary forms make their appearance; which the theory of Häüy explains by supposing that, as the matter which envelopes the primitive nucleus to form a secondary crystal is attracted in thin layers, each layer decreasing in size in consequence of one or more rows of integrant particles being abstracted from its primitive edges or angles. The decrements may be on the edges of the slices, which correspond with the edges of the primitive nucleus; or on the angles, that is, parallel to the

diagonals of the faces of the primitive nucleus; or the decrements may be *intermediate*, parallel to lines situated obliquely between the diagonals and edges of the faces of the primitive nucleus. It would be impossible, however, to give a satisfactory view of this ingenious theory in the narrow compass of this epitome; and therefore I must refer the reader to Haüy's *Traité de Minéralogie*, tomes 1 and 2; to the *Annales de Chimie*, tom. 17; and the 3d volume of the fifth edition of Thomson's *System of Chemistry*.

Such is the attraction of aggregation, and its general effects. It is frequently concerned in modifying pharmaceutical results; but it is a power of much less importance than the next variety of *contiguous attraction*.

b. OF CHEMICAL ATTRACTION, OR AFFINITY.¹

Chemical attraction or affinity is that power by which dissimilar substances placed under certain circumstances are enabled to unite, and form new aggregates, in which the properties of the component particles are lost or changed. Its action is confined to the minute atoms or particles of bodies, and is exerted only at insensible distances: not indifferently, however, between the particles of all bodies, but electively. The result of its operation is a *combination* of the constituent particles of the substances so intimate that the components cannot be recognised, nor separated by any mechanical force. Thus, lime acts as a powerful caustic when applied to animal matter, and is partially soluble in water; phosphoric acid has an acid taste, and is very soluble in water; but phosphate of lime, the compound produced by the chemical combination of these substances, is inert, insipid, and insoluble in water; and cannot be again resolved into lime and phosphoric acid by any mechanical power.

Chemical combination, therefore, is the result of the affinity of two or more substances for each other. It differs from *Mixture*, in which the substances are only blended without acquiring any new properties, and in which the dissimilar parts are easily discovered, and may be separated by mechanical powers. Chemical compounds can, however, be decomposed, either by exposure to a high temperature, which weakens the force of attraction existing between their principles; or by mixture, under favourable circumstances, with some other chemical agent, which has a more powerful affinity for one of its components than these have for each other: and by these means, which constitute *chemical analysis*, the principles of a compound may be ascertained.

¹ The following observations on affinity may be regarded, in a great degree, as an abridgment of the excellent chapter on this subject in the first volume of Dr. Murray's *System of Chemistry*.

As *analysis* separates compounds into their constituent principles, so *synthesis* may reproduce them by recombining these principles; and when this can be effected, it is the surest proof of the accuracy of any analysis. In many instances, however, this is impossible; and the evidence of the truth of an analysis is to be drawn from other sources.

It is an acknowledged law of chemical affinity, that a compound "does not possess properties merely intermediate between those of its component parts, but has acquired others more or less new." One of the most general changes is that of form. The combination of two gases, for example, may produce a fluid or a solid; that of two fluids may form a solid; and the common process of *solution* presents to us the fact, that by the combination of a solid with a fluid, the solid assumes the fluid form. In the last-mentioned instance the fluid is generally regarded as the active substance; but, nevertheless, the attraction of affinity is reciprocal; and hence, the general mode of expressing the fact, that the fluid dissolves the solid, or is the solvent or menstruum, is, in strict language, erroneous. These terms, however, are more correctly applied, when the properties of the solid, except in form, are scarcely sensibly altered; as, for example, when common salt, muriate of soda, is dissolved in water.

Chemical combination produces an alteration of *density*—that of the compound not being the mean of the components, but often different. In the greater number of cases the density is increased; owing probably to a mutual penetration of the components, as there is a diminution of volume; and hence the specific gravity of a compound cannot be determined by calculation from the specific gravity of its ingredients. There are cases of combination, however, in which the density is diminished: and there is an increase of volume in the resulting compound: for instance, when a solid is dissolved by a liquid, the increase of volume acquired by the solid in passing into the fluid state may be greater than the condensation resulting from its union in that state with the liquid; and this happens from the solution of a considerable number of the salts in water.

"The exertion of chemical attraction is accompanied by a *change of temperature*." Thus, if four parts of sulphuric acid and one part of water, both at the temperature of 32° , be mixed together, the temperature of the mixture rises to 300° ; and the density of the compound is much greater than the mean of the densities of the components. The heat also which is evolved by combustion, and in fermentation, is the direct consequence of chemical combination. In all cases the increase of temperature is accompanied with an increase of

density, to which, and the change of form suffered by one or both of the components, its production may be ascribed. Thus steam condensed to water parts with a large portion of caloric; and the same effect is produced when water is solidified by being mixed with quicklime. The contrary effect, however, or an absorption of caloric, is also produced by chemical combination, when the density of the compound is less than the mean; as, for instance, when, by solutions of salts in water, or in some other fluids, very intense colds, greater than any natural cold, are artificially produced.*

The exertion of chemical affinity is influenced by various circumstances: these, according to Berthollet, are mass, cohesion, insolubility, specific gravity, elasticity, and inflorescence.

1. That *mass* has a considerable share in influencing chemical affinity was first suggested by Berthollet, who states it as a canon, that combinations do not depend altogether on the attraction of affinity, but on the proportions also, of the substances brought into action. Thus, if A and B form a compound, and C be a substance which has a stronger affinity for A than B has, it should be able when mixed with the compound to withdraw A altogether from B, if combination was regulated by affinity only: but this he affirms is not the case in fact; for C does not entirely combine with A, but is shared between it and B, according to the force of the affinity, and the bulk of each. This view of the subject affords a reason why, in pharmaceutical compositions, a small quantity of a substance may be added to a compound, without producing any sensible effect, although, if added in large quantity, decomposition would directly ensue. It follows, also, from it, 1st. that "the chemical action of one substance on another, must diminish as it advances to saturation:" and, 2dly, that a decomposing substance "must oppose a stronger resistance to the decomposing agent, in proportion as the decomposition proceeds, from the increase in the relative quantity of one of its ingredients to the other, which is abstracted:" and, lastly, "that in estimating the relative forces of affinity in bodies, the quantities of them must be taken into account, and ought to be equal." Objections have been advanced to the opinions of Berthollet on this subject, yet, as the opposing theories are not fully established, it is unnecessary to enter into an examination of the objections at the present moment.

2. *Cohesion* has an evident influence in opposing chemical action, and counteracting the exertion of chemical affinity. Thus all aggregates are more slowly acted on by liquids in

* See Appendix to Part I. No. I.

which they are soluble, than when their parts are mechanically divided; and this does not happen altogether from the mere circumstance of a larger surface being presented to the fluid; for native oxide of tin, which in the aggregate resists completely the action of any acid, becomes soluble when its aggregation is overcome by mechanical operations; and some other substances are similarly affected. Hence *trituration*, *levigation*, and *granulation* are ranked among pharmaceutical operations, and are of importance "in facilitating chemical action, partly by diminishing aggregation, and partly by increasing the surface on which affinity is exerted." In some instances mechanical division is not sufficient, and recourse must be had to precipitation. Thus liquid potash will not dissolve silica in powder, as it can be obtained by trituration; but when the silica is precipitated from a state of chemical solution, it is readily dissolved in liquid potash.

Owing to the force of cohesion, also, solid bodies seldom act chemically on solids; while fluids readily combine with fluids, and likewise act with energy on solids for which they have an affinity. Fluidity, however, is not indispensable to chemical action; there being many cases in which two solids, in a state of minute mechanical division, act chemically on each other.¹ (See Section iii.) When, however, the specific gravities of even two fluids are very materially different, their chemical combination is opposed, to a certain extent, by the force of cohesion of the heavier fluid; and hence, *agitation* is frequently necessary for aiding the operation of affinity.

Cohesion has sometimes a considerable influence in determining the proportion of combinations formed in consequence of new affinities. Thus, if its intensity be sufficient to counterbalance the affinity of the fluid in which the integrant particles resulting from a new combination are formed, it will combine these, and produce crystallizations or precipitations, which, withdrawing the substance thus formed in part from the sphere of action, and opposing a resistance to any further exertion of chemical power, will consequently determine the proportions of the combination.

3. *Insolubility* must necessarily modify chemical action. If an insoluble compound substance be acted on by any substance tending to combine with one of its principles, this is protected in some degree by the insolubility of the compound withdrawing it from the action of the decomposing substance; and if a compound which is produced in the progress of combination be insoluble, it will be directly precipitated, and thus

¹ Thence the axiom *Corpora non agunt nisi sint soluta*, which was formerly established in chemistry, is not generally true.

fixed in its proportions. In decomposition this is extremely useful; for the insoluble product, being immediately separated, cannot oppose the further action of the decomposing substance, which would be the case were it to remain in solution.

4. *Specific gravity* influences considerably the exertion of affinity, particularly if the substance be of little solubility, by withdrawing it from the sphere of action, and hence retarding its combinations; and in many instances this can be but imperfectly counteracted by agitation.

5. Chemical attraction, as far as the æriform substances are concerned, is opposed by *elasticity*. Thus, when two gases, having mutual affinities, are mixed together, they very seldom combine, which is ascribed to the distances between the particles of substances existing in the gaseous state: for, as chemical attraction is exerted at insensible distances only, the particles of the two gases, although mingled together, are yet without the sphere of attraction. That this is owing to elasticity, is evident from the circumstance that the vapours which are not elastic more readily combine. Hence, whatever gives density to highly elastic substances, as for example, mechanical pressure, or cold to a certain degree, must favour their chemical combination.

6. *Efflorescence* may also influence chemical affinity; a fact which was first observed by Scheele, who ascertained, that if in a paste composed of several saline substances decomposition is going on, one of the resulting compounds often rises through the mass, and forms an efflorescence on its surface; and its being thus withdrawn from the sphere of action contributes towards forwarding the decomposition.

7. The influence of *temperature* in modifying chemical action is very considerable. An increased temperature, by promoting fusion, and in other respects weakening the attraction of cohesion in solids, favours combination; but opposes it in some cases, as much as it augments elasticity. In both instances its effects are much modified by the degree of its intensity; combinations effected at a lower, being often dissolved at a higher temperature, owing to one or more of the components having its affinity weakened by an increased elasticity. Thus, mercury exposed to air for some time at a temperature equal to its boiling point, combines with the oxygen of the air, and is converted into red oxide of mercury; but if the fire be raised so as to make the retort red hot, this oxide is again decomposed, and running mercury and oxygen gas obtained.

From the influence of the above circumstances on chemical combination, the utility of these pharmaceutical and chemical operations, which diminish aggregation, overcome the effect

of specific gravity, diminish elasticity, and regulate temperature, such as pulverization, trituration, granulation, agitation, and compression, with the proper management of furnaces, is sufficiently obvious.

In that department of pharmacy, also, which regards extemporaneous compositions, it is of importance to attend to the slowness with which chemical action is in many instances produced; for substances, which have mutual affinities for each other, may give no indication of any change when newly mixed, but yet, after some time, may act, and produce even complete changes.

Chemical attraction may be exerted between more than two bodies, so as to bring three or four into one combination; and such compounds are named *ternary*, *quaternary*, &c. according to the number of their components. Several examples of these are to be found among the saline preparations (*Part iii.*); and almost all the vegetable substances are compounds of three or more principles.

The forces with which chemical attraction is exerted are different in different bodies. In cases where this attraction is exerted in a superior degree by a third body to either of the components of a compound of two bodies, so as to decompose it, and form a new compound, while at the same time one of the components of the previous compound is set free, the affinity thus exerted has been termed *single elective attraction*. To represent the relative forces of affinity, tables were first constructed by Geoffroy; and afterwards much improved and extended by other chemists, particularly Bergman: but the opinions of Berthollet on this subject have tended very much to lessen their value, although their utility to a certain extent must undoubtedly be acknowledged.¹ When the elective attractions are more complicated, or when two elective affinities are exerted, and two new compounds formed, this is termed *double elective attraction*. In such cases, Mr. Kirwan denominated the attractions which tend to preserve a compound in its original state *quiescent*; while the others which tend to separate the principles of a compound from each other, he termed *divellent attractions*. As an example of double elective attraction, let it be supposed that two compounds, one consisting of potash and sulphuric acid, or *sulphate of potash*, and the other consisting of muriatic acid and lime, or *muriate of lime*, be mixed together, a double decomposition will take place, and

¹ See Appendix to Part I. No. II.

two new compounds, *sulphate of lime*, and *muriate of potash* will be formed. In this case, if the attraction between potash and sulphuric acid be 62, and that between lime and muriatic acid be 20, the sum of the quiescent attractions will be 82; but if the attraction between potash and muriatic acid be 32, and that between sulphuric acid and lime be 54, the sum of the divellent attractions will be 86: which, exceeding the former sum of the quiescent, will operate and produce the above-stated decompositions and resulting compounds.¹

According to the opinions of Bergman, the relative force of the affinities which produce these effects is capable of being measured, and the changes are altogether to be ascribed to the predominance of the affinities of one set of substances over another. But a different and more correct view of the subject has been given by Berthollet, of which we shall now give an outline.

The changes produced by the predominance of certain affinities over others, according to the theory of Bergman, are ascribed by Berthollet to those circumstances which influence attraction, and limit combination. If four substances, for example, be presented to each other, two of which have a greater tendency to cohesion than the other two, so as to form by their union an insoluble compound, instead of one compound being formed by the union of the four, in which the affinities are balanced, this will be averted by the force of cohesion, and the two which form the insoluble compound will unite, and be separated by precipitation or crystallization, leaving the other two in combination in the fluid which has been the medium of action. "If even these four substances were previously in the reverse binary combinations, on presenting them to each other, the affinities within the sphere of action must be reciprocally exerted; and the same extraneous forces will cause an exchange of principles, or the phenomena which have been ascribed to elective affinities will be produced." To avoid the term *elective attraction*, Berthollet denominates cases of this kind *complex affinity*. The explanation of single elective attraction, or where three substances are presented to each other, is pre-

¹ To represent this effect of double elective affinity more clearly, diagrams are used, the idea of which first occurred to Dr. Cullen. Thus the above operations would be represented in the following manner: The inverted triangle in the centre denotes water, or that the decomposition was effected in the humid way.

		Muriate of Potash.			
Sulphate of potash.	Potash	32	Muriatic acid	20=82	Muriate of lime.
	52	▽			
	Sulphuric acid	54	Lime		
		Sulphate of lime.			

cisely the same; the union which takes place between two of them being determined by the tendency to cohesion, or the disposition of the combination of two of them to form a compound of little solubility.

Elasticity likewise has a considerable influence in determining decompositions where the application of heat is necessary; and, according to Berthollet, the decomposition of a compound body, of which one of the ingredients has a great tendency to assume the elastic form, is to be ascribed to the disposition it has to escape from its combination, when aided by the intervention of even a weaker affinity.

In complex affinities the same cause determines the union of substances disposed to assume the elastic form, and separates them as a volatile compound. "If, therefore," says he, "it be desired to know the result of the exposure of two salts to the action of heat, it is only necessary to consider which of the two bases, and which of the two acids have the greater volatility, if there be a difference: for the more volatile base and acid will escape and enter into combination, and the fixed base and fixed acid will remain behind, and combine with one another."¹ Tables representing the forces of affinity have been constructed; but, as Dr. Henry has justly remarked, "one great obstacle to the construction of such tables, is the difficulty of ascertaining, with precision, the quantities of bodies required for neutralization."²

A knowledge of the doctrines of affinity is of the utmost importance in pharmacy; and, as the foregoing sketch presents little more than an outline, I must refer those who would wish to investigate the subject to Thomson's and Murray's Systems of Chemistry, Bergman's Dissertation on Elective Attraction, and Berthollet's Researches into the Laws of Chemical Affinity.

II. REPULSION.

REPULSION is that force which separates the particles of bodies from each other, and consequently counteracts or modifies the attractions by which they are combined and preserved together in masses. It is supposed to depend on the operation of one or more of the three following powers; *Caloric, Light, Electricity.*

a. CALORIC.

The cause of the sensation of heat is denominated *caloric*.

¹ *Researches*, p. 3. quoted by Murray, *System of Chemistry*, i. 120.

² Henry's *Elements of Experimental Chemistry*, 7th ed. vol. i. p. 57.

Philosophers are not completely agreed whether it is a property only of bodies, such as a vibration of their particles¹, or a peculiar substance; but the latter opinion is the one more generally adopted.

Under this opinion caloric is regarded as a very subtle elastic fluid, which penetrates more or less all bodies, passing readily from one to another; and is every where diffused. Its particles are supposed mutually to repel each other; and bodies into which it enters in any sensible quantity are increased in bulk, and undergo other changes of form. It is radiated in the same manner as light, and in this state forms a part of the solar ray.² The rays are refrangible, and capable of reflection. It has no ascertainable gravity; and neither the addition nor the abstraction of it alters sensibly the weight of bodies.³ It exists in two different states; in a free state, in which it is merely loosely mingled as it were, with other bodies; and, in a latent state, or one of intimate combination.

Regarding it as matter, the sources whence it may be obtained, the laws which regulate its motion and distribution, and its effects, require to be noticed.

Sources of Caloric.

The known sources of caloric are the sun, combustion, percussion, friction, and mixture.

a. The sun is an apparent source of caloric; but, the direct action of the sun's rays upon bodies seldom produces a temperature exceeding 120° . When these, however, are concentrated by means of a concave mirror, or a lens; or when means are taken to prevent the communicated heat from being carried off by the surrounding bodies, a much higher temperature can be produced. This source of caloric is not resorted to for pharmaceutical purposes.

b. *Combustion* is a source of caloric highly interesting on account of its utility.

When a combustible is heated to a certain degree, it is consumed, emitting rapidly light and caloric, until the whole substance has suffered a change of properties.

The true nature of this process was first explained by Lavoisier, who laid it down as a chemical axiom, that "in every case of combustion, oxygen combines with the burning body." His explanation of combustion depends on two laws: 1st. That when a combustible body is heated to a certain temperature it immediately begins to attract and combine with the oxygen of the atmospheric air. 2d. This oxygen being in a state

¹ The idea of caloric being motion or vibration, originated with Lord Bacon.

² *Philosophical Trans.* 1807.

³ *Ib.* 1799, p. 179.

of gas, and combined with light and caloric, is decomposed during its union with the combustible, and its caloric and light are set free in a sensible form; while the oxygen itself remains combined with the combustible. The truth of this theory is generally supposed to be proved by the facts, that combustion does not go on unless oxygen be present: and it is more brilliant in oxygen gas than in common air. The products of combustion are always heavier than the body consumed; and this increase of weight is exactly equal to the quantity of oxygen which the air loses. Every combination of oxygen, however, with bodies does not produce the phenomena of combustion. Brugnatelli has endeavoured to explain this by supposing that oxygen combines with bodies in two states: "1. retaining the greater part of the caloric and light with which it is combined when in the state of gas; and, 2. after having let go all the caloric and light with which it was combined."

The above theory of combustion is however liable to some objections; for instance, the emission of caloric and light is not proportional to the quantity of oxygen that combines with the combustible: and the quantity of light that appears depends altogether upon the combustible. Under the supposition, therefore, that the caloric is obtained from the oxygen of the substances supporting combustion, while the light is derived from the combustibles, the process has been regarded as a case of "double decomposition; the oxygen and combustible dividing themselves into two portions, which combine in pairs; the one compound is the *product*," or the combustible base united with oxygen, "the other is the *fire*," or the caloric and light, "which escapes."

The caloric set free by the burning or combustion of coal, charcoal, carbonated hydrogen gas, oil, wax, and tallow, is applied to the purposes of life, and is of the first importance in the practice of pharmacy: thence endeavours have been made to ascertain the quantity of caloric evolved during the burning of different combustibles, and several experiments have been instituted by the most able chemists at different times for this purpose. The following table exhibits the quantity of caloric evolved by the combustion of different substances, the estimate being formed from the quantity of ice melted during the burning of one pound of each of the substances.

¹ Thomson's Chemistry, 4th edit. i. 607.

² Thomson's Chemistry, i. 610.

Substances burnt, 1 lb.	Oxygen consumed in lbs.	Ice melted in lbs.		
		Lavoisier.	Crawford.	Dalton.
Hydrogen - - -	6			
Carburetted hydrogen	4	295	480	320
Olefiant gas - - -	3.5			85
Carbonic oxide - - -	0.58			88
Oil - - - - -	3.5			25
Wax - - - - -	3.5	148	89	104
Tallow - - - - -	3.5	133	97	104
Oil of turpentine -				104
Alcohol - - - -				60
Æther - - - - -	3.			58
Phosphorus - - -	1.5			62
Charcoal - - - -	2.8	100		60
Sulphur - - - - -	1.36	96.5	69	40
Camphor - - - -				20
Caoutchouc - - -				70
				42

From this table it appears that hydrogen gas would form the best fuel, where a high temperature is required.

c. Percussion, as far as it applies to solid bodies, is another source of caloric. Smiths, for instance, are in the habit of kindling their fires by means of an iron rod, which is smartly and quickly hammered until it becomes red-hot; and sparks are produced by the collision of hard bodies, particularly of flint with steel. This effect appears to arise from condensation, or forcing the integrant particles of the bodies closer together, so as to dislodge the latent caloric they contain, and give it out in the form of sensible caloric. The specific gravity of iron is increased .052 by being hammered; and it becomes so hard and brittle that it cannot again be heated by percussion, until it has been exposed for some time to a red heat in the forge. By the collision of flint and steel the oxidization of the steel is also effected, the sparks being small incandescent pieces of oxidized iron.

d. Friction is also a source of caloric. It is a well known fact, that a considerable quantity of free caloric is disengaged when two substances are smartly rubbed together; but the real source of the caloric thus evolved, still remains unknown.

e. Finally, mixture, or the chemical union of two substances, in many cases evolves caloric. This always takes place when the density or specific gravity of the mixture is greater than the mean of the substances mixed; as in the mixture of alcohol and water, or of sulphuric acid and water; and much caloric is also evolved when water is thrown upon quicklime, owing

to the solidification of the water when it unites with the lime. The caloric which is evolved in these, and other instances of mixture, is the latent caloric, which is the cause of the fluidity of the components; for as the compound is less fluid, and consequently requires the presence of a smaller quantity of combined caloric, the superabundance which the more fluid components contained must be necessarily set free.

Such are the sources from which caloric is obtained: combustion is the most important of these; and the knowledge of the laws by which it is regulated, and the modes of conducting it, is of the first consequence in the practice of pharmacy. (See *Furnaces*.)

Distribution and Effects of free Caloric.

From whatever source caloric is obtained, it passes from bodies in which it is accumulated in a free state into bodies which contain less of it, until both are brought to an equilibrium. "The state of a body, with regard to its power of producing the different effects arising from the presence of caloric, is termed its *temperature*;" and this depends on the quantity of sensible caloric contained in it. Thus, when a vessel containing water is placed on the fire, a quantity of caloric passing from the fire into the water, its temperature is raised, or it is made sensibly hotter; and if the water thus heated be taken from the fire and placed in a cold place, the sensible caloric accumulated in it, passes from it into the air and surrounding bodies, until it becomes as cold as they are, or its temperature be lowered to an equilibrium with theirs. The caloric which passes from hot bodies during their cooling is carried off; 1st, by the conducting power of the surrounding medium, which "diminishes as the temperature of the hot body approaches to that of the medium;" 2dly, by radiation; 3dly, by currents, or the repeated change of the portion of medium immediately in contact with the hot body; produced by the change of density occasioned by the caloric it receives from the hot body enabling it to rise and give place to a new portion, which, being heated, is also displaced in its turn, and so on till the temperature of the hot body approaches to that of the medium. By accelerating these changes the rate of cooling is proportionably quickened; and hence the cooling effect of winds, and artificial currents of air.

The temperatures of bodies can be comparatively ascertained to a certain extent by the sensations they induce. Thus, a body containing much sensible caloric feels warm or hot to the touch, owing to its caloric flowing into the hand; and one containing less gives the sensation of cold, owing to the abstraction of caloric from the hand. But this mode of judging of temperature is very limited, and depends on the state of the

sentient organ, and many other external circumstances, which prevent confidence from being placed on it as a comparative measure of temperature: and therefore instruments have been invented to measure the degrees of temperature of different bodies; the properties of which depend on the *expansion* or increase of bulk which bodies suffer when caloric enters into them.

The thermometer is a most useful and important instrument of this kind. It is a hollow glass tube, having at one end a hollow globe or bulb; the hollow of the tube being perfectly cylindrical, and of a small bore, and the bulb of a proportional size. The bulb, and a portion of the tube, after the air is expelled, by holding the bulb over the flame of a lamp, are filled with mercury or coloured alcohol, by immersing the open end of the tube in either of these fluids, and the tube is then hermetically sealed at the extremity.¹ When the bulb of this instrument is applied to a hot body, the mercury, or the fluid it contains, rises in the tube, and continues to do so until the thermometer acquire the same degree of temperature as the hot body, when the mercury becomes stationary, and the point to which it rises indicates the temperature of the hot body. In the same manner when the bulb is applied to a cold body, the mercury contracts and falls in the tube. The quantity which it thus rises or falls, indicating the proportion of increase or diminution of temperature, is ascertained by a scale which divides the tube into a number of equal parts or degrees.

For ordinary purposes, mercury is the liquid best adapted for thermometers; its expansion being most equable; but alcohol is used when great degrees of cold are to be measured.

The thermometer commonly employed in this country is that of Fahrenheit²: but as three other thermometers are used on the continent, it may be proper to notice all of them, and point out the circumstances in which their scales differ.

Fahrenheit, in forming his thermometer, began the scale at the temperature produced by a mixture of snow and sea salt acting on each other; and divided the space between this and the point indicated by the temperature of boiling water into 212 equal parts or degrees; 212° being marked as the boiling point. The part of the scale indicated by the freezing of water, he found to be 32 degrees from its beginning; therefore 32° is marked as the freezing point: and the space between which and the boiling point is equal to 180°. The scale may be extended above this point and also below its

¹ Thermometers of great accuracy may be purchased; but those who may wish to construct them for themselves, will find ample instructions for their guidance, in the third chapter of *Henry's Elements of Experimental Chemistry*.

² Fahrenheit was a German artist.

commencement, the degrees downwards being marked inversely with the same numbers as the ascending scale.

The scale of the thermometer of Celsius, which has been used in France since the revolution, begins at the freezing point of water, which is consequently marked 0, and the space between that and the boiling point is divided into 100 equal degrees; hence it has been named the *Centigrade Thermometer*. Each degree of this scale is $\frac{1}{5}$ ths more than a degree of Fahrenheit's, or one of the latter is equal to $\frac{5}{9}$ ths of a degree of the centigrade scale. To find, therefore, the degrees of Fahrenheit's scale, corresponding to those of the centigrade, the given number of the latter must be multiplied by 9, and divided by 5, adding 32 to the quotient: the sum expresses the degree on the scale of Fahrenheit.

Reaumur's thermometer, which is still used in Italy and Spain, also commences at the freezing point, which is marked 0; and between this and the boiling point it is divided into 80 degree. Each degree is therefore $\frac{4}{5}$ ths more than one of Fahrenheit's; and to reduce those of Reaumur to Fahrenheit's, the given number of the former must be multiplied by 9, and divided by 4, adding 32 to the quotient.*

* TABLE showing the degrees of Reaumur's and Fahrenheit's thermometers corresponding with those of the centigrade thermometer.

Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.
100	80°	212°	68	54°4	154°4	36	28°8	96°8	5	4°	41°
99	79°2	210°2	67	53°6	152°6	35	28°	95°	4	3°2	39°2
98	78°4	208°4	66	52°8	150°8	34	27°2	93°2	3	2°4	37°4
97	77°6	206°6	65	52°	149°	33	26°4	91°4	2	1°6	35°6
96	76°8	204°8	64	51°2	147°2	32	25°6	89°6	1	0°8	33°8
95	76°	203°	63	50°4	145°4	31	24°8	87°8	0	0°	32°
94	75°2	201°2	62	49°6	143°6	30	24°	86°	1	0°8	30°2
93	74°4	199°4	61	48°8	141°8	29	23°2	84°2	2	1°6	28°4
92	73°6	197°6	60	48°	140°	28	22°4	82°4	3	2°4	26°6
91	72°8	195°8	59	47°2	138°2	27	21°6	80°6	4	3°2	24°8
90	72°	194°	58	46°4	136°4	26	20°8	78°8	5	4°	23°
89	71°2	192°2	57	45°6	134°6	25	20°	77°	6	4°8	21°2
88	70°4	190°4	56	44°8	132°8	24	19°2	75°2	7	5°6	19°4
87	69°6	188°6	55	44°	131°	23	18°4	73°4	8	6°4	17°6
86	68°8	186°8	54	43°2	129°2	22	17°6	71°6	9	7°2	15°8
85	68°	185°	53	42°4	127°4	21	16°8	69°8	10	8°	14°
84	67°2	183°2	52	41°6	125°6	20	16°	68°	11	8°8	12°2
83	66°4	181°4	51	40°8	123°8	19	15°2	66°2	12	9°6	10°4
82	65°6	179°6	50	40°	122°	18	14°4	64°4	13	10°4	8°6
81	64°8	177°8	49	39°2	120°2	17	13°6	62°6	14	11°2	6°8
80	64°	176°	48	38°4	118°4	16	12°8	60°8	15	12°	5°
79	63°2	174°2	47	37°6	116°6	15	12°	59°	16	12°8	3°2
78	62°4	172°4	46	36°8	114°8	14	11°2	57°2	17	13°6	1°4
77	61°6	170°6	45	36°	113°	13	10°4	55°4	18	14°4	0°4
76	60°8	168°8	44	35°2	111°2	12	9°6	53°6	19	15°2	2°2
75	60°	167°	43	34°4	109°4	11	8°8	51°8	20	16°	4°
74	59°2	165°2	42	33°6	107°6	10	8°	50°	21	16°8	5°8
73	58°4	163°4	41	32°8	105°8	9	7°2	48°2	22	17°6	7°6
72	57°6	161°6	40	32°	104°	8	6°4	46°4	23	18°4	9°4
71	56°8	159°8	39	31°2	102°2	7	5°6	44°6	24	19°2	11°2
70	56°	158°	38	30°4	100°4	6	4°8	42°8	25	20°	13°
69	55°2	156°2	37	29°6	98°6						

In De Lisle's thermometer, which is used only in Russia, the space between the boiling and freezing points is divided into 150 degrees; the gradation beginning at the boiling point, which is marked 0; and increasing inversely to the freezing point, which is marked 150°. It is seldom mentioned by authors.

These instruments are well adapted for determining the variations of temperature which bodies undergo; but a certain degree of fallacy attends the observations made by them, which is chiefly owing to the expansion of mercury increasing with the temperature. Thus, the medium degree of heat between the freezing and boiling points, although marked on the scale 122°, yet, is actually 118·8° 1' only; the temperature which is equal to raise the mercury in the tube 86 degrees in the first

TABLE exhibiting the degrees of the centrigade and Fahrenheit's thermometers corresponding to those of Reaumur's thermometer.

Reau.	Cent.	Fahr.	Reau.	Cent.	Fahr.	Reau.	Cent.	Fahr.
80	100°	212°	46	57·5	135·5	12	15°	59°
79	98·75	209·75	45	56·25	133·25	11	13·75	56·75
78	97·5	207·5	44	55°	131°	10	12·5	54·5
77	96·25	205·25	43	53·75	128·75	9	11·25	52·25
76	95°	203°	42	52·5	126·5	8	10°	50°
75	93·75	200·75	41	51·25	124·25	7	8·75	47·75
74	92·5	198·5	40	50°	122°	6	7·5	45·5
73	91·25	196·25	39	48·75	119·75	5	6·25	43·25
72	90°	194°	38	47·5	117·5	4	5°	41°
71	88·75	191·75	37	46·25	115·25	3	3·75	38·75
70	87·5	189·5	36	45°	113°	2	2·5	36·5
69	86·25	187·25	35	43·75	110·75	1	1·25	34·25
68	85°	185°	34	42·5	108·5	0	0	32°
67	83·75	182·75	33	41·25	106·25	1	1·25	29·75
66	82·5	180·5	32	40°	104°	2	2·5	27·5
65	81·25	178·25	31	38·75	101·75	3	3·75	25·25
64	80°	176°	30	37·5	99·5	4	5°	23°
63	78·75	173·75	29	36·25	97·25	5	6·25	20·75
62	77·5	171·5	28	35°	95°	6	7·5	18·5
61	76·25	169·25	27	33·75	92·75	7	8·75	16·25
60	75°	167°	26	32·5	90·5	8	10°	14°
59	73·75	164·75	25	31·25	88·25	9	11·25	11·75
58	72·5	162·5	24	30°	86°	10	12·5	9·5
57	71·25	160·25	23	28·75	83·75	11	13·75	7·25
56	70°	158°	22	27·5	81·5	12	15°	5°
55	68·75	155·75	21	26·25	79·25	13	16·25	2·75
54	67·5	153·5	20	25°	77°	14	17·5	0·5
53	66·25	151·25	19	23·75	74·75	15	18·75	1·75
52	65°	149°	18	22·5	72·5	16	20°	4°
51	63·75	146·75	17	21·25	70·25	17	21·25	6·25
50	62·5	144·5	16	20°	68°	18	22·5	8·5
49	61·25	142·25	15	18·75	65·75	19	23·75	10·75
48	60°	140°	14	17·5	63·5	20	25°	13°
47	58·75	137·75	13	16·25	61·25			

instance, being sufficient, by increased expansion, to raise it 94 in the second.

Expansion, or increase of bulk, is the most general effect of caloric, and, with very few exceptions, may be regarded as a general law of its operation.

When caloric flows into a body, it separates its integrant particles from each other, and hence augments its volume. This change is smallest in solids, more considerable in liquids, and most considerable in gaseous bodies; or the expansibility is greater in the inverse ratio of the force of aggregation. Thus, the expansion of air is 8 times greater than that of water; and the expansion of this 45 times greater than that of iron.

The expansion of solid bodies is, in general, so very inconsiderable as not to be easily ascertained by measurement; but, as far as it can be known, it is nearly equable. The degree of expansion, however, is not the same in all solids; thus, for example, the metals expand in the following order, commencing with the least expansible; platina, antimony, iron, bismuth, copper, tin, lead, zinc. Argil is an exception to the law of expansion in solids; for, as has been already remarked, the bulk of pure clay diminishes, when heated, in the ratio of the intensity of the heat to which it is exposed. The cause of this anomaly has not been discovered. The expansion of liquids is more evident than that of solids, but not at all uniform; the differences apparently depending on the fixity or volatility of the components of the liquids: those expanding the most the boiling point of which is lowest; and which, consequently, most readily assume the gaseous form. The degree of their expansion, also, increases, with the augmentation of their temperature; or, the nearer a liquid approaches to the boiling point, the greater is the expansion produced by a degree of caloric; and the further it is from this point, the more equable is the expansion. Liquids, in the same manner as solids, suffer a difference of expansion from a given change of temperature. The following Table, by

¹ For measuring higher temperatures than the thermometer can be subjected to, instruments named *pyrometers* have been employed; the best of which is that invented by Mr. Wedgwood. It depends on the degrees of contraction which pure argil suffers when exposed to high temperatures; and for this purpose small cylinders of pure clay are made in a mould, flattened on one side, and fitted exactly to the wider end of a gauge, consisting of two straight pieces of brass, 24 inches long, fixed on a brass plate so as to converge, and divided into inches and tenths. The length to which the pyrometrical pieces can be slid in the converging groove, indicates the heat to which they have been previously exposed; and as they do not expand again when cold, no fallacy can result from the action of heat on the gauge. Each degree of this scale is equal to 130° of Fahrenheit; and the 0, or commencement of it, corresponds with 1077½° of Fahrenheit's scale. The highest temperature that has been measured by it is 160° or 21877° of Fahrenheit, which is 30° above the point at which cast iron melts. But, as much higher temperatures than this must exist, so also, there are temperatures much lower than can be measured by any thermometer.

Mr. Dalton, shows the expansion of the more common liquids, from 32° to 212° of Fahrenheit, the volume at 32° being denoted by 1.

Mercury.	$\cdot 0200 = \frac{1}{50}$
Water.	$\cdot 0466 = \frac{1}{21.5}$
Water saturated with salt.	$\cdot 0500 = \frac{1}{20}$
Sulphuric acid.	$\cdot 0600 = \frac{1}{17}$
Muriatic acid.	$\cdot 0600 = \frac{1}{17}$
Oil of turpentine.	$\cdot 0700 = \frac{1}{14}$
Ether.	$\cdot 0700 = \frac{1}{14}$
Fixed Oils.	$\cdot 0800 = \frac{1}{12.5}$
Alcohol.	$\cdot 0110 = \frac{1}{9}$
Nitric acid.	$\cdot 0110 = \frac{1}{9}$

To the general law of the expansion of liquids by heat, water furnishes an exception. Thus, from the lowest temperature at which water can remain liquid, to 40° , heat diminishes the bulk of water, instead of expanding it; but above 40° to 212° it expands it.

All gaseous bodies suffer the same expansion by the same additions of caloric, supposing the circumstances to be equal. Their expansion is almost perfectly equable, or the same augmentation takes place by the same addition of caloric at every degree of temperature between the freezing and the boiling point of Fahrenheit's thermometer. By the experiments of Gay Lussac, 100 parts of atmospheric air, heated from 32° to 212° expand 137.5 parts, or $\frac{1}{4.3}$ th for every degree of the thermometer: and the other gases, the steam of water, and the vapour of ether, undergo the same expansions by the same augmentations of temperature. The cause of the equable expansion of gaseous bodies, appears to be the absence of cohesion; so that, at a low temperature, there is no more resistance made to the expansive power of the caloric thrown into the gas, than at a high temperature.

But, besides the change in bulk produced by the introduction of caloric into substances in different quantities, they are changed in state, assuming the *fluid form*, and that of *vapour*; or, they are *ignited*.

Fluidity is an effect of caloric, arising from the repulsive force of the caloric which enters into any substance fitted to take on the fluid form, separating the particles from each other to such a distance as to render them easily moveable on one another in every direction. All solids, with a very few exceptions, are susceptible of the fluid form, when exposed to a suf-

ficient degree of heat; and all liquids, with the exception of alcohol, become solid when exposed to very low temperatures. The particular temperatures necessary for the production of these changes, however, are exceedingly various, but for the same bodies they are always the same.* In some cases, the change is sudden, or the body instantly passes from the solid to the liquid state; in other cases, it passes through several degrees of softness before it be perfectly liquefied: the conversion of ice to water is an example of the first; the melting of glass, of wax, and other unctuous matters, is an instance of the second. There are some bodies, nevertheless, which cannot be melted or *fused*, owing to their suffering chemical decomposition at a lower temperature than is required for their *fusion*:—a piece of wood, for instance, cannot be melted by any application of heat.

Although the melting point, in most cases, is always the same in the same bodies, yet circumstances may vary it; and the admixture of other substances may alter it very considerably. Thus, the melting point of ice, or, what is the same thing, the freezing point of water, is 32° ; but, by exposing water slowly to the action of freezing mixtures, it may be cooled down to 22° before it freezes. The addition of salt renders this point still lower, as may be seen by the following Table.*

Names of salts.	Proportion by weight dissolved in 100 parts of water.	Freezing point.
Common salt	25.	4.
Sal ammoniac	20.	8.
Rochelle salt	50.	21.
Sulphate of magnesia	41.6	25.5
Nitre	12.5	26.
Sulphate of iron	41.6	28.
— of zinc	33.3	28.6

When solids pass to the liquid state they receive an additional quantity of caloric, which combines with them, but does not sensibly elevate their temperature, and this *caloric of*

* Table, showing the degree of temperature, according to Fahrenheit's thermometer, at which several solid bodies melt.

Lead - - - 594°	Copper - - - 4587°	Fahr. 27, Wedg.	Spermacei 112°
Bismuth - 476	Silver - - - 4717	— 28	Phosphorus 100
Tin - - - 442	Iron - - - 21637	— 158	Tallow - - 92
Zinc - - - 700	Sulphur - - - 218		Oil of anise 50
Antimony - 809	Bees-wax - - - 142		Camphor - 303
Mercury - 39	Lard - - - 97		Ice - - - 32

* Phil. Trans. 1788, 27, quoted by Dr. Thomson—Syst. Chemistry, 4th edit. i. 520.

b

fluidity, or *latent heat*, as it has been named, is again given out in a sensible form, when the body returns to a solid state. If water, for example, be exposed to a great degree of cold, and kept free from agitation, it may be cooled several degrees below the freezing point, and yet remain fluid; but if it be then agitated, it instantly congeals, and at the moment its temperature rises to 32° . All fluids, therefore, are combinations of solids and certain doses of caloric. Thus, if snow at 32° be mixed with an equal weight of water at 172° , the snow instantly melts, but the temperature of the mixture is only 32° ; so that 140° of caloric have disappeared or become latent: hence the quantity of caloric necessary to give fluidity to ice is 140° . These facts were first ascertained by Dr. Black in 1762; and fluidity in general has been proved to depend on a similar cause. Softness, plasticity, malleability, and ductility, probably depend also upon the repulsive force of the latent heat which combines with bodies.

Vapour, which is another effect of caloric, is that state into which all fluids and some solids pass when their temperature is raised to a certain point, or caloric is thrown into them in sufficient quantity to separate their integrant particles to distances beyond the sphere of the attraction of cohesion. The fluid passes to the *aëriform* state, becoming invisible and elastic, and possessing the other mechanical properties of air.

Evaporation, however, is also spontaneously produced, and besides being the conversion of a fluid to the state of vapour by the agency of caloric alone, seems to depend on the solvent power of atmospheric air, forming a solution of the body in the *aërial* fluid. By *spontaneous evaporation*, the fluid is gradually converted into the *aëriform* state at every temperature. Water, alcohol, ether, and volatile oils are susceptible of spontaneous evaporation, so that a portion of any of them exposed to the air in a flat vessel soon altogether disappears; "but sulphuric acid and the fixed oils never assume the form of vapour till they are raised to a certain temperature."

All fluids have a fixed point of temperature at which their vaporization commences, which is denominated their *boiling point*, and beyond this point fluids cannot be heated if freely exposed to the air, so as to allow the vapour to escape as it forms. Thus water at 212° boils, and is progressively converted into steam at the bottom of the vessel, which, rising in bubbles through the water, produces the ebullition that characterizes boiling; but although the fire be raised ever so much, yet the temperature of the water never exceeds 212° ; the vapour carrying off every additional increment of heat in a latent form. The boiling point varies in different bodies;

and in the same body also, if it be placed under different circumstances, particularly with regard to pressure. Thus the boiling point of ether is 98° , of alcohol 176° , water 212° , mercury 660° , and so on. In a vacuum all liquids boil at a temperature 145° lower than in the open air; and in Papin's digester, in which water can be heated under a great pressure, the temperature may be raised to 300° without ebullition. Owing to this circumstance, highly volatile substances, as ammonia and ether, cannot be easily manufactured in elevated situations.

The elasticity of the vapour of liquids boiled in the open air is equal to that of the circumambient atmosphere; but under pressure, so that the temperature of the vapour may be much augmented, the elasticity increases with the temperature. At low temperatures, on the contrary, vapours lose their elasticity, are condensed, and return to their fluid state. The conversion, therefore, of liquids into elastic fluids depends on the same cause as the conversion of solids into fluids; namely, "to the combination of a certain dose of caloric with the liquid, without any increase of temperature."¹ The vapour carries off all the caloric which enters a body after it arrives at its boiling point; and retains it in a latent form: for the vapour is not hotter to the senses or the thermometer than the boiling liquid: thus, steam, the temperature of which is indicated by the thermometer to be 212° , is water combined with 940° of caloric, which remain latent as long as the temperature of the steam is maintained, but is again given out when a lower temperature changes that vapour to the state of a liquid.

Gases resemble vapours in their constitution, and differ from them only in the greater reduction of temperature which is required for their condensation, some of them not being reducible by ordinary pressure, or by any known reduced temperature, to the fluid or solid state. They are nevertheless very probably compounds of solid or liquid substances and caloric. Indeed several of the gases have been condensed into fluids, by the application of cold and pressure; oxymuriatic acid gas, for instance, becomes liquid at a little under 40° , and forms solid crystals at 32° ; and ammoniacal gas condenses into a fluid at 45° .

Ignition is another effect of caloric, but differing altogether from expansion, fluidity, and evaporation, which may in some measure be regarded as different degrees of one general effect. It implies an emission of light from bodies which are much heated, or combined with a large portion of caloric, without

¹ The important discovery of the causes which produce the changes of bodies from the solid to the liquid and æiform state was made by Dr. Black in 1760.

their suffering any change of composition. It is totally independent of the presence of air, and is a simple effect of caloric. Aëriform substances are not susceptible of ignition.

The degree of temperature at which all bodies capable of ignition begin to be ignited, or become red hot, is nearly the same,—about the 800th degree of Fahrenheit; and by raising the temperature the illumination increases, until a perfectly white light is produced, which is the highest point of ignition. Ignition is supposed to arise from the extrication of the light, which is regarded as a constituent of the ignited body, by the repulsive agency of the additional caloric; but this explanation of the phenomenon is liable to some objections, and the real cause remains still undetermined. As a pharmaceutical agent, caloric is of the first importance, in the majority of cases producing decomposition; but in others favouring combination. The decomposition most easily effected by it is the separation of the more volatile from the more fixed ingredients of compounds. Thus in the process of distillation (see *Operations*), when weak spirits are heated, the alcohol separates from the water, owing to its superior volatility, and by condensation is obtained as a distinct substance. Almost all compounds into which oxygen has entered without having occasioned combustion, as nitric acid, hyperoxymuriatic acid, and some metallic oxides, suffer likewise decomposition by caloric. All compound bodies containing combustibles are also decomposable by it; as are also compounds consisting of two or more combustible ingredients, in combination with oxygen, as almost all animal and vegetable matters. On the contrary, the compounds which are little or not at all affected by caloric, as far as regards the composition, are those which have been formed by combustion; such as water, phosphoric acid, and carbonic acid.* The proper application of caloric for the purpose of obtaining new combinations by lessening the force of aggregation, and thus favouring the attraction of affinity; or for producing decompositions by weakening or destroying altogether the force of these attractions, so as to obtain the principles of bodies in a distinct state, constitutes the most important feature of operative pharmacy. (See *Operations*.)

2. LIGHT.

Light is a substance consisting of very subtle particles which are constantly emanating in straight lines from luminous bodies. The size of these is too minute to be appreciated; but their velocity is estimated to be at the rate of 200,000 miles in a second. They appear to repel each other like those of caloric.

* Thomson's Chemistry, 4th edit. i. 546.

A ray of light falling upon a polished surface is *reflected* from it at an angle equal to the angle of its incidence.

When a ray of light moving in a straight line passes within a certain distance of a body parallel to its direction, it bends towards the body, or is *inflected*; but when the body parallel to its course is at a greater distance, the ray is bent from it, or *deflected*. When it passes obliquely from one medium to another of a different density, it is bent a little from the line of its former direction, and assumes a new one, or is *refracted*. In passing into a denser medium it is refracted towards the perpendicular; but from the perpendicular when passing into a rarer medium. The refraction is proportional to the density of the medium, but in that of a combustible the refraction is greater than the ratio of its density.

Every ray of light is resolvable into seven other distinct rays, each possessing a different degree of refrangibility; and consequently divisible from each other by the prism. The ultimate or component rays are distinguishable by the impression of colours they excite on the eye; and are arranged in the following order, *red, orange, yellow, green, blue, indigo, violet*. The red is the least refrangible, reflexible, and inflexible; the violet the most; and that of the others follows the order in which they are placed. The colour of bodies depends on their transmitting or reflecting those rays only which excite the impressions of their colour. The reflection of the whole prismatic rays constitutes white; the absorption or suffocation of all or the greater part of these occasions black, which is the total absence of light.

The illuminating power of the rays of light differs. Those towards the middle of the prismatic spectrum, as above arranged, possess the greatest illuminating power; but this diminishes as the rays approach towards the extremities.

Light enters into combination with bodies; and in some cases is again extricated without any change being produced, as in *pyrophori*, or substances which absorb light, and emit it again when carried into a dark place. In some cases, however, the absorption of light by bodies occasions very sensible changes in them: the colour of plants, for example, their taste and odour, and the quantity of combustible matter they contain, depend on light: for a plant reared in the dark is nearly colourless, insipid, inodorous, and contains a very small proportion of combustible matter.

The natural sources of light are the sun and fixed stars; but it is also artificially produced by combustion, chemical combination, heat, and percussion. The sun's rays, the greatest source of light, have been found to be composed of three dif-

ferent species of rays; 1. rays which produce light and colour; 2. rays of mere heat; and, 3. rays which produce neither light nor colour, nor affect the thermometer; but which have the power of deoxidizing: and, thus constituted, it produces very important chemical effects.

Light partially deoxidizes metallic oxides and salts. Thus it blackens muriate of silver; and as this takes place when the salt is placed beyond the violet ray, or out of the prismatic spectrum, the effect is apparently to be attributed to the action of the third species of rays. It also reduces the nitro-muriatic solution of gold, when it is placed in contact with charcoal, or any other vegetable, or any animal matter; and the red oxides of mercury and of lead become much lighter when exposed to the sun; the rays that produce these effects are the least refrangible. Dr. Wollaston, however, has pointed out one exception to this effect of these rays, in guaiacum, which becomes green or oxidized in the least refrangible rays; and is again changed to yellow, or deoxidized in the most refrangible.

Light has a powerful tendency to decompose liquid oxy-muriatic acid; and also nitric acid, which it renders red and fuming, even when it is contained in vessels accurately closed. Almost all the vegetable and animal colouring matters have their brilliancy and colour much impaired by long exposure to the sun's rays: they affect also the colour and the properties of vegetable powders kept in clear glass bottles. Light even seems to have a strong influence on the process of crystallization; for, if light be only partially admitted to a crystallizing solution, the crystals will be larger and more numerous on the enlightened side; and often the whole mass will radiate towards this point. Chaptal¹ found that by using a solution of a metallic salt, and shading the greater part of the vessel, capillary crystals shoot up the uncovered side, and the extent of the exposed part is distinctly marked by the limit of the crystallization.

Such are some of the properties of light, the chemical effects of the operation of which seem to be perfectly independent of its heating power; and there is even reason to believe that the greatest chemical changes are produced by the invisible rays: for Ritter² affirms that, by transmitting the coloured rays through different prisms, he has separated them from the invisible or chemical rays, and obtained a coloured spectrum devoid of any chemical power.

3. ELECTRICITY and GALVANISM.

THE phenomena of electricity depend on a very subtle fluid, which is a powerful chemical agent, capable of producing im-

¹ *Journal de Physique*, xxxiii. 297.

² *Nicholson's Journ.* viii. 216.

mediate decompositions and new combinations. Galvanism appears to be essentially the same as electricity, differing however, in some degree in its effects and the mode of its production. Both are to be regarded as repulsive powers.

a. *Electricity* may be communicated to all substances: by some it is transmitted without any perceivable obstruction, but by others with much difficulty: hence bodies in their relation to electricity are distinguished into two classes, *conductors* and *non-conductors*: and as it can be accumulated in the latter by friction and other means, these are also denominated *electrics*; while the former are named *non-electrics*, to indicate their incapability of being excited.

Metals, water, and charcoal are conductors: all other substances are non-conductors; although many of these, when made very hot, become conductors. All electrics or non-conductors when rubbed, as, for instance, a glass rod with a piece of woollen cloth, attract light substances; and, when a conductor is approached to them, exhibit an appearance of light, attended with a peculiar sound and smell. Some electrics can be excited by simple heating or cooling. It is necessary, however, for obtaining any considerable excitation, that the rubber have some communication with the earth; from which it appears that the great source of electricity is in the earth, and that excitation consists in the mere transferring of the electrical fluid from one substance to another. By rubbing electrics on each other, the distribution of the electric fluid they contain is altered; and on separating them, more than the natural quantity remains with the one, and less with the other: the one is then said to be electrified *plus*, and the other *minus*, or *positively* and *negatively*. When two bodies are both electrified positively, or both negatively, they repel each other; but if one of them be electrified positively, and the other negatively, they attract each other. Instead of this distribution of the same fluid, the existence of two fluids has been assumed, each of which repels its own particles, but attracts those of the other; and this assumption is more favourable for the explanation of the chemical agency of this fluid.

The chemical effects of electricity seem to depend chiefly on its power of producing a sudden high temperature; and this appears to be proportioned to the resistance opposed to its transmission. It often favours chemical combinations, as that of oxygen with the metals, and promotes the instantaneous chemical union of gaseous bodies. It also effects chemical decompositions, as those of water, ammonia, alcohol, and metallic oxides. But for neither purpose is it employed as a pharmaceutical agent.

b 4

b. Galvanism may be regarded as a modification of electricity, in which the fluid is evolved during certain chemical actions. It is transmitted through those substances which are conductors of common electricity, and with the same degrees of facility and rapidity. The metals, charcoal to a certain extent, plumbago, water, the mineral acids, and saline solutions, are perfect conductors; water, alcohol, ether, sulphur, oils, resins, and metallic oxides, are imperfect conductors: but glass, dried and baked woods, the dry animal cuticle, and dry gases, are non-conductors of the galvanic fluid.

Galvanism is generally excited by arranging two different metals, as, for instance, copper and zinc, and a fluid, as nitric acid, diluted with twenty or thirty parts of water, in such a manner that the metals touch each other in one part, and have the fluid interposed between them in another.¹ The metals soldered together in pairs are placed transversely in the grooves of a well seasoned wooden, or an earthenware trough, and fixed in with a cement of resin and wax, to prevent any liquid from passing through; after which, the diluted acid is poured between the pairs, so that it touches the zinc of one pair, and the copper of another, alternately, the copper side of each double plate looking towards the same extremity of the trough throughout the arrangement, and the zinc side to the other extremity. This apparatus is named the galvanic battery; and the distances between the pairs of soldered plates should be from one-fourth to three-fourths of an inch each, according to the width of the trough. The intensity of action of this apparatus, as far as the production of heat is concerned, seems to depend on the size of the plates, or extent of surface; but, for producing chemical decomposition, on the number of plates, the more improved apparatus now used, is a trough of earthenware, divided in its length by numerous partitions of the same material. Into each of the cells thus formed, and filled with the diluted acid, a plate of zinc and of copper are placed, but not so as to touch each other; and a communication is made by a metallic arc between the zinc in one cell, and the copper in the next.

As a chemical agent, galvanism is the most powerful of all the repulsive forces, and is capable of producing decompositions which could not otherwise be effected. By its means the chemical constitution of the alkalies and the earths has been established, and their bases discovered to be substances hitherto unknown, which have been added to the list of metals.

¹ The pile of Volta, which is not now employed, consists of plates of zinc and silver, and pieces of moistened woollen cloth, piled in the order of zinc, silver, cloth; zinc, silver, cloth, for twenty or more repetitions.

By placing a compound, one, for instance, of oxygen and an inflammable body, in connexion with the metallic wires proceeding from each end of a galvanic battery, the oxygen is attracted by the wire that is in the positive state, and repelled by that which is negative; while, at the same time, the inflammable is attracted by the negative wire, and repelled by the other. Hence the components are separated, and obtained in an insulated state. In the decompositions thus effected, substances can be conveyed to a distance, and even through interposed ponderable matter, by the galvanic influence; a result which, however singular, is well ascertained.

Galvanism, like electricity, acts as a stimulus to the living system. Its effects on the animal body are a sensation of light when applied to the eye; a sensation of acidity on the tongue; and the excitement of strong muscular action.

It would be entering too much into hypothetical discussion to attempt an explanation of the phenomena of galvanism; particularly as philosophers are not yet agreed upon the subject. Galvanism has not yet been employed as a pharmaceutical agent.

On the forces of attraction and of repulsion every chemical, and consequently every pharmaceutical effect, more or less depends. A knowledge, therefore, of the laws which regulate these powers is of the greatest importance, and forms the basis of all chemical science.

SECTION II.¹

EVERY substance, whether it be regarded generally as forming a part of the mass of this globe, or particularly as an object of science, may be arranged in one or other of the three following classes; *Solids*, *Fluids*, and *Gaseous Bodies*. We shall now examine each of these classes separately, and endeavour to describe the constitutions and combinations of the substances composing them, inasmuch as they are objects of pharmacy.

I. SOLIDS.

SOLID bodies are masses of homogeneous particles combined and held together by the attraction of aggregation or cohesion. The arrangement of the particles with regard to each other is

¹ In drawing up this section, I have borrowed very freely from the third book of Thomson's *System of Chemistry*, 4th edition.

often such as to produce regular figures, in which case the solids are said to be crystallized. Cohesion and crystallization have been already considered.

A. CONSTITUTIONS OF SOLIDS.

Arrangement of the principal Solids according to their Composition.

I. SIMPLE, or UNDECOMPOUNDED.

Sulphur. Carbon. Metals.

II. COMPOUNDS.

Phosphorus.

Oxide of Sulphur.

———— *Phosphorus.*

Charcoal.

Metallic Oxides.

Sulphurets of Metals.

———— *fixed Alkalies.*

———— *Earths.*

Phosphurets of Carbon.

———— *Metals.*

———— *Earths.*

Carburets of Iron.

Alloys.

Solid Acids.

Earths.

———— *with Earths.*

———— *metallic Oxides.*

———— *fixed Alkalies.*

Salts and Hydrosulphurets.

Metallic Oxides with Alkalies.

Bitumens.

Soaps.

Most vegetable Substances.

Many animal Substances.

SIMPLE SOLIDS.

a. SULPHUR. Although the experiments of Sir H. Davy have unequivocally proved that hydrogen is always present in sulphur as we obtain it; yet, they afford no positive conclusion that it is an essential ingredient of sulphur. I have therefore followed Dr. Thomson in regarding it as a simple solid. For its properties, see PART II. p. 389.

b. CARBON. The diamond is this substance in a state of purity; and, although, charcoal in its ordinary state almost invariably contains either hydrogen or water, yet, from the

experiments of Messrs. Allen and Pepys, it is probable that charcoal is essentially as pure carbon as the diamond, and that the hydrogen it evolves depends on water which it always absorbs on the shortest exposure to the air. Carbon is a constituent of almost all vegetable and animal substances.

c. **METALS** are simple inflammable bodies, of great specific gravity, density, and opacity; and, as the result of these qualities, possess great brilliancy or lustre from their power of reflecting almost all the light which falls upon their surface. Their colours are generally shades of white, gray, or yellow; their hardness is considerable, and according to its degree they are more or less elastic: one only, mercury, is in a fluid state at the ordinary heat of the air. Many of them possess considerable tenacity, and are hence malleable and ductile; but some are extremely brittle. Metals are sapid and odorous when heated or rubbed; their fracture is generally hackly; their texture fibrous or foliated; and many of them are sonorous. They are excellent conductors of caloric, electricity, and galvanism. When exposed to the action of caloric, they expand and are melted; but differ greatly with regard to fusibility; some of them are volatilized at known temperatures. When fused, their surface is convex and globular; and in cooling they generally crystallize. They are very susceptible of oxidizement.

The following metals are used as pharmaceutical agents.

I. MALLEABLE.

- | | |
|---|-------------------------------------|
| 1. Silver. (<i>See Part ii. p. 43.</i>) | 5. Tin. (<i>Part ii. p. 384.</i>) |
| 2. Mercury. (<i>Ibid. p. 204.</i>) | 6. Lead. (<i>Ibid. p. 310.</i>) |
| 3. Copper. (<i>Ibid. p. 145.</i>) | 7. Zinc. (<i>Ibid. p. 417.</i>) |
| 4. Iron. (<i>Ibid. p. 171.</i>) | |

III. BRITTLE AND EASILY FUSED.

- | | |
|---|--|
| 1. Bismuth. | 3. Arsenic. (<i>Part ii. p. 48.</i>) |
| 2. Antimony. (<i>Part ii. p. 39.</i>) | |

III. BRITTLE AND DIFFICULTLY FUSED.

1. Manganese. (*Part. ii. p. 247.*)

Bismuth is a reddish white coloured metal of a lamellar texture. Its specific gravity is 9.822. It fuses at 476° Fah. and crystallizes on cooling; in a higher temperature volatilizes; and on the access of air burns with a blue flame, emitting a yellow smoke, which is an oxide of the metal. The mineral acids act on it; and it readily combines with sulphur and most of the other metals.

a. **BORON** is obtained from the decomposition of boracic acid, in the form a deep olive coloured powder, insipid and inodorous. It undergoes no change at any temperature when

heated in close vessels; but takes fire and burns like charcoal, when heated in the air to about 600° . During combustion it attracts oxygen and is converted into boracic acid. It is also converted into the acid by decomposing sulphuric and nitric acids when it is treated with them. It combines with the alkalies and sulphur. Sir H. Davy conceives it is a compound; and that one of its ingredients which enters into alloy with potassium and with iron, is the real basis of boracic acid.

b. COMPOUNDS OF SULPHUR.

1. *Oxide of Sulphur* is formed on the surface of sulphur which is kept for some time in a state of fusion. It has a violet colour, and a fibrous texture; is austere to the taste, tough; and its specific gravity is 2.325. It contains rather less than 7 per cent. of oxygen.
2. *Sulphurets of metals* are compounds of sulphur and metals, inodorous and insipid, often possessed of metallic brilliancy, brittle; and are conductors of electricity. Three of them only are officinal.

Table of Officinal Sulphurets of Metals.

Sulphurets.	Colours of the Sulphurets.	Specific Gravity.	Sulphur United to 100 metal.
Mercury {	1. Black - - }	8.16	8
	2. Red - - }		16
Iron - - {	1. Yellow - }	4.518	57.1
	2. Yellow - }	4.83	114.2
Antimony	Leaden gray	4.368	37.25

3. *Sulphurets of fixed alkalies* are opaque, solid bodies, of a brownish red or liver colour; decomposable by caloric, water, and acids; and which, by exposure to the air, are converted into hydrogureted sulphurets.
Officinal. Sulphuret of potash, (*Part ii. p. 562.*)
4. *Sulphurets of earths* resemble the alkaline sulphurets in their properties.
5. *Hydrosulphurets* are compounds of sulphureted hydrogen with alkalies and earths. They are soluble in water, crystallizable, and are decomposed by the atmosphere and acids.
- b. PHOSPHORUS is semitransparent, of a yellowish red colour, and a waxy consistence, but when perfectly pure is colourless and transparent. Its specific gravity is 1.770. It may be cut with a knife, is brittle at a temperature under 32° , but above that point softens, and under 90° is very ductile. It melts

at 90° ; in close vessels is volatilized at 219° ; and boils at 55° . When heated in the air to 148° it inflames, and emits a white smoke, which has an alliaceous odour, and condenses to an acid. It is obtained from urine, bones and other animal matters; and by Sir H. Davy's experiments appears to be a compound of an unknown base with hydrogen.¹

1. *Oxide of phosphorus* produced by the exposure of phosphorus to dry air, has the appearance of fine white flakes, which take fire when slightly heated, and burn with a very vivid flame: by the further exposure to the air they attract moisture, and are converted into an acid.

2. *Phosphuret of carbon* (the substance which remains in the leather through which new-made phosphorus is strained, purified by exposure to heat in a retort,) is a light flocculent powder, of a bright orange, or rather red colour, insipid, and inodorous. It burns rapidly when heated in the air, and leaves charcoal behind.

Phosphurets of metals are generally brittle, and have a metallic lustre. (Vide *Annales de Chimie*, tom. i. & xiii.)

4. *Phosphurets of earths* have a brown colour; are generally luminous in the dark; insoluble in water, but decompose that fluid, furnishing phosphureted hydrogen gas.

c. CHARCOAL? (Part ii. p. 87.)

d. METALLIC COMPOUNDS.

1. *Alloys* are compounds of two or more metals. They have generally lustre, hardness, tenacity, ductility, and other properties of the metals; but these properties in alloys differ from those of the metals from which they are formed. The compounds of mercury with other metals are named *amalgams*.

2. *Metallic oxides* are generally in the form of powders, or friable fragments not at all resembling the metals; sometimes laminated and crystallized; of various colours, determinate with regard to the metals and their treatment; heavier than the metals; and refractory, or fusible into glass. Some are insipid, others acrid and styptic; in general they are insoluble in water, and combine with acids, or with alkalies, or with both at the same time. They are reducible by light, by caloric, hydrogen, carbon, oils, &c.²

¹ For experiment, the simplest mode of obtaining phosphorus is to mix a solution of phosphate of soda with a solution of acetate of lead, in the proportion of one part of the former salt to one quarter of the latter. This will yield a precipitate of phosphate of lead, from which phosphorus may be obtained by distillation.

Henry's *Elements of Chemistry*, ii. p. 7.

² As the same metal is susceptible of different degrees of oxidizement, it has been found necessary to designate the oxides thus formed by distinct appellations, indicative

Table of officinal metallic oxides, showing the quantity of oxygen united to 100 of metal by weight in each.

Metals.	Colour of Oxides.	Oxygen in 100 parts.	Metals.	Colour of Oxides.	Oxygen in 100 parts.
Silver - -	Olive	7.925	Zinc - -	White	24.41
Mercury {	Black	4	Bismuth -	White	11.28
	Red	8	Antimony	Yellow	18.60
Iron - - {	Black	29.5	Arsenic {	White	34.93
	Red	44.25		Do.	52.4
Lead - - {	Yellow	7.70			
	Red	11.08			
	Brown	15.60			

3. *Carburet of iron (plumbago)* is of a dark blue or gray colour; has some degree of metallic lustre, a greasy feel, is soft, and blackens the fingers. It is not altered by water or by air, nor affected by the most violent heat, if air be excluded; the acids do not affect it; it detonates with nitrate of potash, and reduces the metallic oxides. 100 parts appear to consist of 5 of iron, and 95 of carbon; with, perhaps, a minute proportion of hydrogen.

4. *Metallic phosphurets.*

5. *Metallic sulphurets.* Metals combine with different quantities of sulphur. The sulphurets are brittle, generally destitute of lustre, and differing in colour from the metals that form their basis.

6. *Metallic oxides with alkalies.*

7. *Earths. (Part iii. p. 479.)*

Earths with earths.

————— *metallic oxides.*

————— *alkalies.*

e. *SOLID ACIDS and SALTS* in a crystallized state, contain a portion of water in their composition. The following are objects of pharmacy, or officinal:

1. *Phosphoric acid* is solid, colourless, transparent, and resembles glass in appearance; is inodorous, very acid, reddens vegetables blues, and deliquesces when exposed to the air. Its specific gravity in a state of dryness is 2.687. It is very soluble in water, dissolving with a

of the comparative quantity of oxygen with which the metals thus formed are combined. The terms *protoxide*, *deutoxide*, *tritoxide*, and *peroxide*, imply that a metal is in its first, second, third and ultimate stage of oxidizement. — These terms were proposed by Dr. Thomson.

hissing noise; and is decomposed at a high temperature by carbon, hydrogen, and several of the metals: 100 parts consist of 46.72 of phosphorus, and 53.28 of oxygen.¹

Phosphate of lime constitutes the basis of bones, from which it is procured in the state of a white powder by calcination, and solution in muriatic acid, from which it is precipitated by ammonia. It is inodorous, insipid, insoluble in water, but is decomposed by several of the acids: exposed to a heat of 378° Wedgewood, it softens, and changes to an enamel: 100 parts contain about 50.8 of acid, and 40.2 of lime.

Subspecies. 2. *Bi-phosphate of lime.*

Subspecies. 3. *Quadri-phosphate of lime.*

Subspecies. 4. *Sub-phosphate of lime.*²

Phosphate of soda. (Part iii. p. 477.)

2. *Boracic acid* is obtained in the form of white thin hexagonal scales, greasy to the feel. It reddens vegetable blues, is inodorous, but has a sour bitterish taste, leaving a cooling, sweet impression in the mouth. Its specific gravity is 1.479. It is fixed in the fire, but melts into a hard transparent glass. Boiling water dissolves only two parts of boracic acid: alcohol dissolves it, and the solution burns with a green flame; and oils also dissolve it with the assistance of heat. It oxidizes only iron, zinc, and perhaps copper? Its components are, according to the experiments of Sir H. Davy, one part by weight of borax, and two of oxygen.

Sub-borate of soda. (Part iii. p. 371.)

3. *Benzoic acid.* (Part iii. p. 427.)

4. *Succinic acid.* (Part iii. p. 442.)

5. *Oxalic acid*, generally obtained by treating sugar with nitric acid, is in the form of white, transparent, shining, four-sided prisms, which have a very acid taste, redden vegetable blues, and are soluble in their own weight of boiling water. Exposed to heat in open vessels, it is decomposed. According to Berzelius, 100 parts contain 52 of real acid, and 48 of water; and the acid Dr. Thomson³ found to be a compound.

6. *Tartaric acid* is obtained in white, irregular, hard, semitransparent crystals, the specific gravity of which is 1.5962. It readily dissolves in water; is capable of oxidizing iron, zinc, and mercury; and combines with

¹ Rose.

² Thomson's *System of Chemistry*, 5th edit. vol. ii. p. 459.

³ *Ibid.* p. 155.

alkalies, earth, and metallic oxides, forming tartrates. The crystallized acid consists of real acid 100 parts, water 13.43, and 100 parts of the acid of oxygen 64, carbon 32, hydrogen 4—100; are composed of 59.882 of oxygen, 34.167 of carbon, and 3.951 of hydrogen.¹

Tartrate of potash. (Part iii. p. 469.)

Variety. *Supertartrate of potash.* (Part ii. p. 391.)

Tartrate of potash and soda. (Part iii. p. 471.)

7. *Citric acid.* (Part iii. p. 429.)

For descriptions of the remaining solid salts, (see Part iii.)

f. *BITUMENS.* (Part ii. p. 70.)

g. *SOAPS.* The true nature of these compounds has been illustrated by Chevrueil. He found that the fatty matter they contain consists of two distinct substances, which he has named *Steirin* and *Elain*. These, by the action of salifiable bases, are converted into two acids, the *margaritic* and the *oleic*; and soaps are merely combinations of one or both with alkaline, earthy, or metallic bases. The alkaline soaps have a peculiar, unpleasant odour and taste, form a milky solution with water, and a transparent one with alcohol; are powerfully detergent, and are decomposed by the earthy and the metallic salts. 2. The earthy soaps are insoluble in water, and not detergent. 3. Metallic soaps are likewise insoluble in water, but some of them are soluble in alcohol, and others in oil.

1. *Hard soap.* (Part ii. p. 360.)

2. *Soft soap.* (*Ibid.* p. 361.)

Variety. *Liniment of ammonia.* (Part iii. p. 735.)

3. *Liniment of lime-water.* (Part iii. p. 735.)

h. *SOLID VEGETABLE SUBSTANCES.* It is necessary to notice in this place the solid proximate principles only of the vegetable substances which are officinal, or employed as pharmaceutical agents. The constituents of the whole of them are—carbon, hydrogen, oxygen, and azote, in different proportions.

1. *Sugar.* (Part ii. p. 351.) It is soluble in nitric acid, and yields oxalic acid.

Variety. *Manna?* besides common sugar, contains mucilage and a nauseous substance to which it owes its purgative properties. When digested with nitric acid, it yields saccharic as well as oxalic acid. It does not ferment like sugar.

2. *Sarcocoll* is usually in oblong, semitransparent, yellow, globules, which have a bitter sweet taste, and an odour resembling in some degree that of anise seed. It does not

¹ Berzelius.

crystallize. Soluble in water and alcohol. Treated with nitric acid yields oxalic acid.

Variety. *Liquorice?* Dissolves in nitric acid, and forms tannin; and when treated with sulphuric acid yields about one-fourth of its weight of charcoal. It is not susceptible of fermentation.

3. *Gum.* (Part ii. p. 4.)

Official. *Acacia Gum.*

Variety. *Mucus.* Inodorous, insipid, soluble in water, insoluble in alcohol; not precipitated by silicated potash, but precipitated by alcohol in a fibrous state.

Official. Linseed mucus, quince seed mucus, marsh mallow mucus.

4. *Cerasin.* This substance, which was formerly confounded with gum, is the produce of the *astragalus tragacantha*. For its physical properties, see (Part ii. p. 64.) With nitric acid it yields saccharic, malic, and oxalic acids.

Varieties. *Cherry tree gum? Congo gum; Dominica gum.*

Official. *Tragacanth.*

5. *Ulm*[†]. This is a spontaneous exudation from the elm; but, as Berzelius has hinted, is probably a component of every bark. It is solid, black, hard, shining, and insipid. Soluble in water, but does not form mucilage; insoluble in alcohol; precipitated by nitric and oxymuriatic acids in the state of resin.

6. *Inulin* is obtained from the *Inula helenium* in the form of a white powder, which is insoluble in cold water and in alcohol. It is soluble in boiling water, forming a mucilaginous solution; but precipitates as the solution cools. Treated with nitric acid it yields malic and oxalic acids.

Official. *Elecampane root.*

7. *Starch.* (Part ii. p. 400.)

Varieties. *Potatoe starch; Salop; Tapioca.*

8. *Gluten* is of a gray colour, nearly insipid and inodorous, very tenacious, ductile, and elastic; partially soluble in water, and soluble in acetic and muriatic acid. Insoluble in alcohol and ether. When treated with nitric acid it yields oxalic acid.

9. *Fibrin* is tasteless, fibrous, elastic, and resembles gluten. It is insoluble in water, alcohol, and diluted alkali: but is soluble in acids, particularly nitric acid. It soon putrefies.

10. *Extractive* is obtained by evaporating aqueous vegetable infusions to dryness. It has a strong taste; and is

[†] So named by Dr. Thomson.

soluble in water; but insoluble in alcohol and ether, unless when the extractive is united with resin. It is precipitated from its solutions by oxymuriatic acid, muriate of tin, and muriate of alumina; but not by gelatin.

Officinal. Catechu, most barks, &c.

11. *Emetin*. This substance is obtained from ipecacuanha and some other roots which have an emetic property. It is in the form of brownish-red transparent scales, inodorous, but having a bitter and slightly acrid taste. It is very soluble in water, alcohol, and acetic acid, but insoluble in ether. Nitric acid converts it into oxalic acid. Half a grain, when swallowed, excites full vomiting.*

Officinal. Ipecacuanha root.

12. *Nicotin* is obtained from the leaves of several species of nicotiana. It is colourless, acrid, and has the odour of tobacco; is soluble in water and alcohol; and approaches the volatile oils in its properties. It is extremely poisonous.

Officinal. Tobacco leaves.

13. *Tannin* has a bitterish, astringent taste; is soluble in water, and in alcohol of 0·810. It is precipitated by the muriates of tin and of alumina, and by gelatins.

Officinal. Galls, uva ursi, tormentil, rhubarb, cinchona barks, swietenia, simarouba, kino, catechu, willow bark.

14. *Wax* is a fixed oil saturated with oxygen. (*Part ii.* p. 102.)

15. *Camphor*. The ultimate components are probably carbon and hydrogen, the proportion of carbon being greater than in oils. (*Part ii.* p. 226.)

16. *Scillitin*. This substance is procured from the bulb of the squill. It is white, transparent, and pulverulent: has an intensely bitter taste leaving a sweetish impression on the palate. It is soluble in water and alcohol, and when heated swells and exhales the odour of caromel.

Officinal. The bulb of the squill.

17. *Resins* are brittle, semitransparent, yellowish substances, inodorous, and having an acrid taste. Their specific gravity varies from 1·0452 to 1·2289. They melt when heated, inflame in a higher temperature, and burn with a strong

* To obtain *Emetin* treat powder of ipecacuanha with ether at 60°, as long as it acts upon it: then boil the powder several times with fresh quantities of alcohol at 40°, and filter the boiling solutions, which will throw down as they cool a white flocculent precipitate: filter again and evaporate the clear solution in a water-bath. Melt the reddish residue which will be obtained, with cold water, and add magnesia, which will precipitate the *Emetin* that may be now obtained in a state of purity by dissolving the precipitate in alcohol, and evaporating the solution to dryness.

yellow flame, emitting much smoke. They are insoluble in water; but soluble in alcohol, ether, alkalies, and acetic acid. Nitric acid converts them into artificial tannin.

Officinal. Amber, copal, pine resins, mastiche.

18. *Guaiacum* differs from resins in being soluble in nitric acid, and yielding, when treated with it, oxalic acid, and no tannin.

19. *Pierotoxine* is procured from the fruit of *Menispermum cocculus*, in white, four-sided prismatic crystals; of an intensely bitter taste, soluble in twenty-five times its weight of water, and in three times its weight of alcohol and of ether. It is insoluble in oils. Nitric acid converts it into oxalic acid. It is intoxicating, and poisonous when swallowed.

Officinal. *Cocculus Indicus*.

20. *Morphia*. This is an alkaline substance procured from opium. It is in white pyramidal crystals, scarcely soluble in boiling water, but very soluble in alcohol and ether. It combines with the acids forming neutral salts. It acts with great energy on the animal economy.

Officinal. Opium, lactucarium.

21. *Balsams* resemble resins in their appearance; have a strong aromatic odour; yield benzoic acid when heated, or dissolved in sulphuric acid; and when treated with nitric acid yield artificial tannin.

Officinal. Balsams of tolu, benzoin, storax.

22. *Gum resins* resemble resins in their appearance; but are odorous, form milky solutions with water, and transparent solutions with alcohol. They are soluble in alkalies; and are converted into tannin by nitric acid.

Officinal. Ammoniacum, galbanum, scammony, assafoetida, myrrh, sagapenum.

23. *Wood* which forms the support of all vegetables, is composed of tasteless fibres, insoluble in water and alcohol; but soluble in weak alkaline ley; and in nitric acid yielding oxalic acid. When distilled *per se*, at a red heat, it leaves much charcoal.

i. SOLID ANIMAL MATTERS.

1. *Gelatin*. (Part ii. p. 12.)

2. *Albumen* when dried is a brittle, transparent, glassy substance, resembling gum in appearance. It is soluble in cold water, and when the solution consists of one part of dry albumen and 9 of water, heat coagulates it into a firm white solid mass: alcohol, ether, and the strong acids also coagulate the solution.

Officinal. White of egg.

3. *Solid oils* are composed, like the other fixed oils, of a

solid and a fluid substance which Chevreul has named *Stearin* and *Elain*.

Varieties — *a. Spermaceti.* (Part ii. p. 296.)

b. Fat is an odorous, insipid, white crystalline substance; greasy to the touch; melts at 140° ; vaporized at 400° , the vapour being inflammable. Insoluble in water, alcohol, and ether; combines with alkalies, and forms soap; and is decomposed by strong acids.

Official. Lard, mutton suet, fat.

4. *Castor.* (Part ii. p. 94.)

5. *Musk.* (Part ii. p. 259.)

6. *Bones and Shells.* (Part ii. p. 278.)

7. *Horn.* (Part ii. p. 104.)

COMBINATION OF SOLIDS WITH SOLIDS.

Although solid bodies may be made to enter into combination with each other, yet all do not combine in the same manner, and under similar circumstances. Thus, some unite in any proportion; and some in certain determinate proportions only; while others will not combine with each other in any manner.

1. TABLE of the principal Solids which have been ascertained to be capable of uniting in any Proportion.

Sulphur with phosphorus.

Carbon with iron?

Metals with most metals.

Protoxide of antimony with sulphuret of antimony.

Earths with earths.

Earths with some metallic oxides.

Some earths with fixed alkalies.

Solid oils with each other, and with bitumen.

All the products are solids, except that of the first, which is liquid.

None of these solids combine spontaneously, even although placed in contact; but require to be mixed, and exposed to a degree of heat capable of melting one or both of them; in which case the caloric breaking the force of the cohesive attraction which retains the particles of the solids in the aggregate state, the atoms of the one substance are brought into immediate contact with those of the other, or within the sphere of the attraction of affinity, which consequently acts and produces the new compound. The compounds do not very materially differ in their properties from their constituents, except the compounds of iron with carbon, and some of the earths with each other. The combination, however, is generally accompanied with a change of density.

2. TABLE of the principal Solids which have been observed to unite only in determinate proportions.

Sulphur with metals.

_____ some metallic oxides.

_____ earths.

_____ fixed alkalies?

Phosphorus with carbon.

_____ metals.

_____ some earths.

Acids with alkalies.

_____ earths.

_____ metallic oxides, &c.

These enter into more intimate union than the preceding. They, however, do not unite when both bodies remain in the solid state; "except sulphur and the fixed alkaline hydrates, some acids, and a few hydrates of metallic oxides, and perhaps some of the acids, and the fixed alkaline hydrates:" hence they are brought into union, either by *fusion*, or by *solution in water*, or some other liquid menstruum. By the first mode, "sulphur is made to combine with metals, earths and fixed alkalies, and phosphorus with metals:" by the second, the acids are combined with the alkalies, earths, and metallic oxides. The mode of union resembles that of liquids with solids in every respect.

It is important to ascertain the *proportions* in which these bodies unite, and their *change of density*. Berthollet is of opinion, that sulphur may unite indefinitely with the metals, the proportion of sulphur varying indefinitely in many native sulphurets; but Dr. Thomson¹ maintains the contrary opinion, owing to the circumstance "that when sulphur and a metal are fused together, we obtain always the two bodies combined in determinate proportions."

The following Table (drawn up by the latter) compares the results of the analysis of metallic sulphurets, with a calculation founded on the supposition that the metals and sulphur unite atom to atom; that the weight of an atom of sulphur is 13; and that of an atom of the respective metals is as stated in the first column. The second column gives the weight of sulphur united to 100 parts of the metal by calculation; the third by analysis.

¹ Alkalies in the crystalline form, or containing water solidified.

² *System of Chemistry*, 4th edit. iii. 136.

Metals.	Weight of a metallic atom.	Weight of sulphur combined.	
		By calculation.	By experiment.
Silver	95.7	14	17.6
Bismuth	93.7	14	17.5
Arsenic	54.5	24	25.
Copper	48.0	27	14 to 30
Mercury	120.0	10.8	17.6
Tin	48.0	27	17.6
Lead.....	150.0	8.7	12 to 25
Antimony.....	80.0	16.2	33.3
Iron	32.4	40	60 to 112

The metallic sulphurets are rarer than the mean of their components, owing to the substances expanding during their union sometimes more than one-fifth of the whole. Pyrites, however, is an exception, its specific gravity being greater than the mean.

Nothing precise is known of the other combinations of sulphur, or of those of phosphorus with solid bodies.

The combinations of the acids with alkalis, earths, and metallic oxides are well understood. When an acid and an alkali are mixed together, we find that, after several small additions of the alkali to the acid, diluted with a little water, the mixture still retains acid properties; but by continuing to add the alkali these disappear, and alkaline properties are acquired by the next addition that is made: the acid or the alkaline properties of the compound, therefore, predominate according to the proportions of each; but there are certain proportions, according to which they destroy, by their union, the properties of each other, so that neither predominates. In this case they are said to *neutralize* each other; the products are named *neutral salts*, and the proportions in which the acids and alkalis unite to form neutrals are *fixed and determinate*.

All salts, however, are not neutrals; but in some the proportions of the acid, in others, that of the base, predominate. The former, which are named *super-salts*, are supposed to be compounds of two atoms of the acid with one of the base; and the latter, which are named *sub-salts*, of two atoms of the base with one of the acid.¹ Thus supertartrate of potash consists of one atom of potash united to two of tartaric acid; or by weight, of 5.23 parts of base, and 100 of acid²: while carbon-

¹ For an account of the Atomic Theory, I must refer my readers to Mr. Dalton's writings, and Thomson's *Annals of Philosophy*, passim.

² Berzelius.

ate of potash consists of two atoms of potash and one of carbonic acid; or by weight, of 2.75 of acid and 6.00 of base. *Triple salts*, are salts composed of one acid united to two bases at the same time, — as the tartaric acid, for instance, with potash and soda, to form the tartrate of potash and soda.

The metalline salts are seldom neutral, having generally an excess either of acid or base.

II. LIQUIDS.

It has been already observed, that by throwing caloric into a solid body, or, in other words, heating it, the force of the attraction of cohesion which preserved it in the solid state is gradually weakened, and finally overcome. When the particles of a body which were at a low temperature immoveable relatively to each other, are separated by interposed caloric, so as to move easily upon each, but are yet within the limits of the sphere of the attraction of aggregation, the body is denominated a *liquid*, provided it remain in this state under the medium temperature of the atmosphere. Thus *Ice*, when brought into a place the temperature of which exceeds 32° , loses its solidity and becomes a liquid or water, which form it retains in every degree of temperature between 32° and 212° on the scale of Fahrenheit's thermometer. Let us now examine the constitution of liquids; their combinations with other liquids; and their combination with solids.

1. OF THE CONSTITUTION OF LIQUIDS.

Liquids may be regarded as compounds of caloric with a solid base. Their parts move easily upon each other, and yield to the smallest impression; but they are not sensibly elastic. The greater or smaller degree of liquidity of different substances depends upon a difference of the force of cohesion exerted between their particles, which may be regarded as placed in the limit between attraction and repulsion: thus the cohesion of mercury is greater than that of water. Liquids differ very much in specific gravity¹; and the degree of this bears a relation to their density. "The distances of the atoms are so regulated, that the attraction and repulsion by which they are at once actuated just balance one another; while their form is such, that they can move freely among each other without altering these distances. It is this which seems to constitute the real cause of liquidity."

All liquids may be arranged into two great classes. "The following Table² exhibits a list of almost the whole of them arranged according to their composition."

¹ See No. IV. of Appendix to Part I.

² Thomson's *Chemistry*, 5th edit. iii. p. 84.

I. SIMPLE.

Mercury. (*Part ii.* p. 203.)

II. COMPOUND.

a. Simple gases combined.

Water.

Nitric acid. (*Part iii.* p. 436.)

b. Gases with a solid base.

Sulphuric acid. (*Part ii.* p. 8.)Alcohol. (*Part iii.* p. 636.)Ethers. (*Ibid.* p. 665.)Volatile oils. (*Ibid.* p. 576.)Fixed oils. (*Ibid.* p. 70.)Petroleum. (*Part ii.* p. 70.)

Supersulphuret of hydrogen.

Oxymuriate of tin.

c. Solidis combined.

Phosphuret of sulphur.

Sulphuret of carbon.

If mercury be excepted, all the known liquids are compounds; and the greater number of them contain water as an ingredient.

Water. The ordinary appearances and properties of this liquid are too well known to require description. Its maximum of density is at the temperature of 36° . A cubic foot of it, at 30 inches of the barometer, and 55° of the thermometer, weighs 998.74 avoirdupoise ounces of 437.5 grains troy each. Its specific gravity is supposed = 1.000, and it is made the standard of unity in the measurement of the gravity of every other liquid. The gravity of ice is less than that of liquid water. In the form of steam it occupies 1800 times the space which it does in the form of water. It is not decomposed by heat alone; nor altered by light: but is decomposed by iron, zinc, antimony, and tin, when assisted by heat. It readily absorbs air and gases¹; and is a constituent of all gases. It is a compound of oxygen and hydrogen, 100 grains containing 88.286 of oxygen, and 11.714 of hydrogen.² It liquefies a great number of solid bodies, its solvent power being increased by diminishing the pressure of the atmosphere; and, as has been already stated, the greater number of liquids contain it as an ingredient.

Supersulphuret of hydrogen is a transparent, colourless liquid

¹ From Mr. Dalton's experiments, it appears that water absorbs its own bulk of carbonic acid gas, of sulphureted hydrogen gas, and of nitrous oxide, $\frac{1}{2}$ of oxygen gas, nitrous gas and carbureted hydrogen; and $\frac{1}{4}$ of carbonic oxide, azotic gas and hydrogen gas.

² Biot and Arago.

when pure, but more frequently has a greenish-yellow tinge. It has a strong peculiar odour, and a pungent yet cooling taste. Its specific gravity is 1.3. It burns like spirit of wine, and during the combustion emits a sulphurous odour. It is a compound of 96.75 parts of sulphur, and 3.25 of hydrogen.

Oxymuriate of tin is a transparent liquid, which exhales a very heavy dense smoke when exposed to the air. Twenty-two parts of it united with seven of water condense into a solid mass. It yields by evaporation small crystals, which are deliquescent, and sublime in a moderate heat.

Phosphuret of Sulphur is of a yellowish colour, and exceedingly inflammable.

Sulphuret of Carbon is a transparent colourless liquid, having an acrid, pungent, slightly aromatic taste and foetid odour. It is very inflammable, burning with a blue flame, and emitting fumes of sulphurous acid. It is a compound of 84.83 parts of sulphur, and 15.17 of carbon.

2. COMBINATION OF LIQUIDS WITH EACH OTHER.

When liquids are mixed together they either unite in any proportions, or in certain determinate proportions only, or they cannot be united, but separate, howsoever carefully they be mixed together; or they decompose each other.

I. TABLE of Liquids which unite when mixed together in any proportions, and do not afterwards spontaneously separate.

Water with alcohol.

————— nitric acid.

————— sulphuric acid.

Alcohol with ether.

Sulphuric acid with nitric acid.

Fixed oils with petroleum.

————— volatile oils.

————— fixed oils.

Volatile oils with petroleum.

————— volatile oils.

When these liquids are mixed together, such a mutual penetration takes place, that every portion of the mixture contains the same proportions of both ingredients; and this is the case although there may be the greatest difference in the specific gravity of the individual liquids. Agitation assists the rapidity of this effect very much, but the mixture is never perfect until some time afterwards. If, on the contrary, agitation be not employed, the mixture is always more quickly effected when the denser liquid is added to the rarer; for in the opposite case a long period often elapses before it be completed. A partial muddiness occurs when even transparent liquids of different

densities are mixed together, and continues until the mixture be perfect; but when it is complete, the compound is homogeneous, and the liquids do not afterwards separate from each other.

As the density and specific gravity of a compound thus formed are always greater than the mean, caloric is evolved during the mixture. In some cases the quantity is scarcely sensible; but in other cases it is capable of affecting considerably the thermometer: thus, if fixed and volatile oils, be mixed, the temperature is not very sensibly raised; but if four parts of sulphuric acid and one part of water, both at 32° , be mixed together, the temperature rises to 212° . When equal parts of sulphuric acid and water are mixed, the density is augmented by 13 per cent.; of nitric acid and water, the increase is equal to one-twelfth; and when water and pure alcohol are mixed, it is rather more than one-twenty-eighth of the whole weight. These mixtures are cases of real chemical combination; the force which holds them combined being that of chemical attraction exerted between the integrant particles of the two liquids.

II. TABLE exhibiting a list of the Liquids that unite with each other only in certain proportions.

Water with ether.

———— volatile oils.

———— sulphuret of carbon.

———— oxymuriate of tin.

Alcohol with volatile oils.

———— petroleum.

———— supersulphureted oxygen?

———— phosphuret of sulphur?

Ether with volatile oils.

———— petroleum.

Volatile oils with petroleum.

Water dissolves rather less than one-tenth of its bulk of sulphuric ether; and the proportion of volatile oil it takes up is also very minute; being scarcely more than is sufficient to communicate its odour to that liquid, without any other of its properties. It has been already stated, that twenty-two parts of the fuming oxymuriate of tin mixed with seven of water unite and condense into a solid mass. Although alcohol unites readily with the volatile oils, yet the quantity of each is limited: and the proportion of petroleum which alcohol dissolves is also very small. The proportions of volatile oils and petroleum which ether dissolves are considerable.

The affinity of the compounds of this table is much weaker than of those of the former; which, "with the difference between the cohesion of the particles of the two liquids, li-

mits the combination to certain proportions." They are also more easily decomposed; for, if a spirituous solution of volatile oil be poured into water, the alcohol leaves the volatile oil to unite with the water, while the greater part of the separated oil swims on the surface of the new compound.

III. TABLE *exhibiting the principal Liquids which do not sensibly combine in any proportion.*

Water with petroleum.
————— fixed oils.
————— supersulphureted hydrogen.
Fixed oils with alcohol.
————— ether.
Mercury with water.
————— alcohol.
————— ether.
————— volatile oils.
————— petroleum.

In these cases the affinity between the two liquids is not sufficient to overcome the cohesion between the particles of each liquid. The spreading of oil, however, upon the surface of water, and adhering to it, is supposed to depend on the exertion of some degree of affinity, although less than is requisite to produce a combination of the two liquids.

If a liquid have an affinity for one of the constituents of another liquid, although not for the liquid itself, it frequently decomposes it, and forms new compounds.

IV. TABLE *of the principal Liquids which decompose each other.*

Water, by phosphuret of sulphur.

Nitric acid, by all the liquids, except water and sulphuric acid.

Sulphuric acid, by all the liquids, except nitric acid and water.

During the first case of decomposition, which is facilitated by a high temperature, sulphureted and phosphureted hydrogen exhale, and sulphuric and phosphoric acids are formed.

The combinations of solids, reduced to the liquid state, are regulated by the very same laws as those of proper liquids.

3. OF THE COMBINATION OF LIQUIDS WITH SOLIDS.

The principal liquids, the action of which upon solids has been examined, are *water, alcohol, ether, petroleum, volatile oils, fixed oils, mercury*, and the *acids*, which have been already noticed.

a. Water enters into combination with solid bodies in two states. In the first the proportion of solid matter exceeds

that of water, and the liquid becomes a part of the solid body without rendering it liquid; in the second, the solid is much exceeded by the quantity of fluid, which liquefies it, and imposes its peculiar form upon the compound. The products of the first state are denominated *hydrates*; the second constitutes *solutions*.

I. TABLE of *hydrates* or compounds of solid bodies and water, still retaining the solid form.

1. *Sulphur* is found native in the state of a hydrate; but the hydrate most generally known is precipitated sulphur, (*Part* iii. p. 389.)
2. *Metallic oxides*, when in the state of hydrates, are powders possessed of very intense colour, having usually a strong taste, and being easily acted upon by acid or alkaline solutions.
3. *Earthy hydrates* are powders, and sometimes crystals.
4. *Alkaline hydrates* are what are commonly termed the crystals of alkalis.
5. *Acid hydrates* are those acids which are generally procured in a solid state, and known under the name of crystallized acids.
6. *Saline hydrates* comprehend the whole class of saline preparations, whether assuming the form of crystals, powders, or solid masses.
7. *Hydrates of hydrosulphurets* are the crystallized hydrosulphurets.
8. *Soaps* are hydrates, water being always present in them as a constituent.
9. *Tannin* and many animal and vegetable solids.

In the two last classes the proportion of combined water does not appear to be determinate, although this is the case with all the others.

Solution. — During solution, both bodies, or the solid and the liquid, act mutually upon each other at the same time; and the force exerted by each is equal to its mass. The action goes on at the point of contact only: hence, as far as the mass is concerned, the quantity of liquid has no effect in hastening the solution. When a solid body is plunged into a liquid, if the affinity between them be weak, the combination of the two goes on as long only as the force of the affinity is able to overcome the force of cohesion of the particles of the solid; when it stops, the compound remains solid, and is consequently a *hydrate*. But if the affinity be strong, the cohesion of the solid is gradually destroyed, and its particles being united with those of the liquid are dispersed equally through it, forming a *solution*. By the addition, however, of new portions of the solid, the

action of the liquid is gradually weakened; and at length, being unable to overcome the cohesion of the solid, no more of it is dissolved. In this case, the sums of the force of the attraction of affinity exerted between the solid and the liquid, and of the force of the cohesive attraction of the particles of the solid for each other, are balanced; and the liquid is said to be *saturated*. The union of the two bodies is effected by chemical combination. If a portion of the liquid be now abstracted, (as for example by evaporation,) the force of the cohesive attraction of the particles of the solid becomes again superior to the force of the affinity which separated them, so that the solid is reproduced. When this is slowly accomplished, it produces crystallization, the phenomena of which have been already noticed.

In the formation of hydrates the increase of density is often very great, and much caloric is evolved. Thus, hydrate of lime is specifically heavier than pure lime. Hydrate of alum, which is simply crystallized alum, has a specific gravity of 1.7065; but when its water is driven off by calcination, the gravity is reduced to 0.4229; and crystallized nitrate of potash, or hydrate of nitre, is of the specific gravity 1.9639; but nitre deprived of its water of crystallization is only 1.7269.

The density of solutions is greater than the mean, when pure solids are employed; but when it is the hydrates which are dissolved, the specific gravity is more generally less than the mean. The following useful Tables, drawn up by Hassenfratz, show the specific gravity of saline solutions containing different proportions of salt, at 55°. By consulting them we can readily know the exact quantity of salt contained in any saline solution of a specific gravity corresponding with the numbers marked in the tables; and when the gravity of the solution is not found in the tables, its saline contents can still be found by calculation.

¹ The salts were generally in the crystallized state. The column belonging to each salt terminates at the point of saturation, at the temperature of 55°.

TABLE OF SALINE SOLUTIONS.

Weight of Salt in 100 parts of the Solution.	Sul- phate of Soda.	Sul- phate of Potash.	Alum.	Weight of Salt in 100 parts of the Solution.	Sul- phate of Mag- nesia.	Sul- phate of Iron.	Sul- phate of Zinc.	Sul- phate of Copper.
1	1'0039	1'0086	1'0047	2	1'0096	1'0096	1'0080	1'0141
2	1'0078	1'0171	1'0094	4	1'0192	1'0203	1'0165	1'0280
3	1'0116	1'0257	1'0142	6	1'0286	1'0314	1'0255	1'0413
4	1'0154	1'0343	1'0189	8	1'0379	1'0436	1'0345	1'0539
5	1'0192	1'0429	1'0236	10	1'0470	1'0560	1'0440	1'0660
6	1'0230	1'0515		12	1'0555	1'0696	1'0540	1'0795
7	1'0268			14	1'0646	1'0829	1'0665	1'0938
8	1'0306			16	1'0711	1'0961	1'0790	1'1083
9	1'0344			18	1'0771	1'1095	1'0915	1'1230
10	1'0381			20	1'0860	1'1220	1'1040	1'1380
11	1'0418			22	1'0976	1'1358	1'1165	1'1513
12	1'0455			24	1'1092	1'1498	1'1290	1'1747
13	1'0492			26	1'1178	1'1638	1'1420	
14	1'0528			28	1'1324	1'1781	1'1550	
15	1'0564			30	1'1440	1'1920	1'1680	
16	1'0598			32	1'1557	1'2031	1'1820	
				34	1'1675	-	1'1960	
				36	1'1789	-	1'2100	
				38	1'1905	-	1'2240	
				40	1'2122	-	1'2380	
				42	1'2262	-	1'2525	
				44	1'2302	-	1'2680	
				46	1'2432	-	1'2855	
				48	1'2562	-	1'3045	
				50	1'2683	-	1'3310	
				52	1'2833	-	1'3485	
				54	1'2973	-	1'3565	

TABLE OF SALINE SOLUTIONS—continued.

Weight of Salt in 100 parts of the Solution.	Muriate of Soda.	Muriate of Potash.	Hyperoxymuriate of Potash.	Muriate of Ammonia.	Muriate of Barytes.	Weight of Salt in 100 parts of the Solution.	Muriate of Magnesia.	Muriate of Lime.
1	1'0064	1'0047	1'0055	1'0029	1'0073	2	1'0068	1'0125
2	1'0128	1'0095	1'0105	1'0059	1'0146	4	1'0136	1'0212
3	1'0192	1'0143	1'0150	1'0089	1'0217	6	1'0204	1'0319
4	1'0256	1'0192	1'0193	1'0118	1'0289	8	1'0274	1'0429
5	1'0320	1'0240	1'0220	1'0149	1'0360	10	1'0340	1'0540
6	1'0384	1'0288	1'0301	1'0179	1'0430	12	1'0408	1'0650
7	1'0448	1'0338	1'0376	1'0209	1'0503	14	1'0476	1'0759
8	1'0502	1'0388	1'0461	1'0239	1'0575	16	1'0554	1'0870
9	1'0576	1'0438	1'0567	1'0269	1'0647	18	1'0612	1'0979
10	1'0640	1'0490	- -	1'0300	1'0720	20	1'0681	1'1000
12	1'0775	1'0612	- -	1'0358	1'0919	22	1'0751	1'1212
14	1'0910	1'0701	- -	1'0416	1'1014	24	1'0823	1'1323
16	1'1045	1'0801	- -	1'0474	1'1309	26	1'0895	1'1445
18	1'1182	1'0901	- -	1'0532	1'1504	28	1'0967	1'1547
20	1'1320	1'1000	- -	1'0590	1'1700	30	1'1040	1'1670
22	1'1462	1'1090	- -	1'0642	1'1901	32	1'1114	1'1803
24	1'1608	1'1178	- -	1'0693	1'2227	34	1'1190	1'1935
26	1'1760	1'1264	- -	- -	1'2363	36	1'1266	1'2067
28	1'1920	1'1344	- -	- -	1'2600	38	1'1343	1'2198
30	1'2100	1'1420	- -	- -	- -	40	1'1420	1'2330
						42	1'1507	1'2478
						44	1'1597	1'2528
						46	1'1686	1'2789
						48	1'1777	1'2949
						50	1'1870	1'3120
						52	1'1963	1'3310
						54	1'2068	
						56	1'2164	
						58	1'2261	
						60	1'2380	
						62	1'2507	
						64	1'2646	

TABLE OF SALINE SOLUTIONS—continued.

Weight of Salt in 100 parts of the Solution.	Nitrate of Potash.	Acetate of Lead.	Acetate of Iron.	Tartrate of Soda.	Tartrate of Potash.	Phosphate of Soda.	Borax.	Soda of Commerce.	American Potash.
1	1'0063	1'0070	1'0035	1'0034	1'0050	1'0040	1'0040	1'0042	1'0050
2	1'0125	1'0140	1'0075	1'0072	1'0102	1'0081	1'0084	1'0086	1'0102
3	1'0186	1'0211	1'0112	1'0108	1'0153	1'0120	1'0122	1'0130	1'0156
4	1'0244	1'0263	1'0150	1'0148	1'0212	1'0166	-	1'0175	1'0212
5	1'0302	1'0366	1'0188	1'0190	1'0258	1'0200	-	1'0220	1'0259
6	1'0353	1'0430	1'0225	1'0231	1'0311	1'0237	-	1'0264	1'0327
7	1'0408	1'0505	1'0264	1'0272	1'0363	1'0270	-	1'0310	1'0385
8	1'0468	1'0580	1'0302	1'0313	1'0417	1'0300	-	1'0356	1'0443
9	1'0531	1'0655	1'0341	1'0355	1'0470	-	-	1'0403	1'0503
10	1'0595	1'0731	1'0380	1'0397	1'0525	-	-	1'0458	1'0563
12	1'0722	1'0891	1'0458	1'0481	1'0634	-	-	1'0544	1'0684
14	1'0850	1'1055	1'0537	1'0567	1'0744	-	-	1'0640	1'0807
16	1'0984	1'1221	1'0616	1'0655	1'0856	-	-	1'0736	1'0930
18	1'1119	1'1330	1'0697	1'0745	1'0968	-	-	1'0833	1'1053
20	1'1235	1'1560	1'0780	1'0887	1'1080	-	-	1'0930	1'1179
22	1'1389	1'1740	1'0863	1'1082	1'1196	-	-	1'1031	1'1307
24	1'1520	1'1928	1'0948	1'1153	1'1317	-	-	1'1135	1'1438
26	-	-	1'1045	1'1293	1'1447	-	-	1'1241	1'1571
28	-	-	1'1140	1'1436	1'1569	-	-	1'1349	1'1724
30	-	-	1'1224	1'1600	1'1700	-	-	1'1460	1'1840
32	-	-	1'1323	1'1801	1'1838	-	-	-	1'1989
34	-	-	-	-	1'1978	-	-	-	1'2142
36	-	-	-	-	1'2118	-	-	-	1'2304
38	-	-	-	-	1'2259	-	-	-	1'2478
40	-	-	-	-	1'2400	-	-	-	1'2660
42	-	-	-	-	1'2547	-	-	-	1'2882
44	-	-	-	-	1'2696	-	-	-	-
46	-	-	-	-	1'2861	-	-	-	-
48	-	-	-	-	1'3015	-	-	-	-
50	-	-	-	-	1'3180	-	-	-	-
52	-	-	-	-	1'3351	-	-	-	-
54	-	-	-	-	1'3527	-	-	-	-
56	-	-	-	-	1'3707	-	-	-	-
58	-	-	-	-	1'3902	-	-	-	-
60	-	-	-	-	1'4120	-	-	-	-

If a new substance be added to the saturated solution of another substance, the result is different according to the nature of the matters employed. Sometimes the second substance is not dissolved: thus a saturated solution of muriate of lime at 60° cannot dissolve any common salt. Sometimes the whole, or a part of the new solid, is dissolved without any of the already combined solid being lost or precipitated: thus a saturated solution of nitrate of potash at 51° can dissolve more muriate of soda than pure water, and the same is the case with nitrate of soda; but in the latter case, a great portion of the nitrate is precipitated. Sometimes the new solid is dissolved at the expence of the whole of the substance already dissolved, which is consequently precipitated: thus, if a sufficient quantity of muriate of soda be added to a saturated

solution of muriate of ammonia at 61° , the former salt is dissolved, but the whole of the latter precipitates during its solution. This last result, however, does not take place at every degree of temperature; for at a boiling heat muriate of soda is separated by those very salts which it precipitates at a low temperature.

b. Alcohol acts less extensively upon solids than water; and it forms no solid combinations similar to the hydrates.

Table of the solids which Alcohol is capable of dissolving.

1. Sulphur.
2. Phosphorus, and its compounds.
3. Fixed alkalies.
4. Some of the alkaline earths in minute portions.
5. Most of the solid acids.
6. Many salts.
7. Alkaline sulphurets.
8. Alkaline soaps.
9. Tannin, and many vegetable substances.

A mixture of water and alcohol appears to possess greater energy as a solvent in many cases than either of them in a separate state.

c. The action of ether upon solids is still more limited than that of alcohol.

d. The action of mercury as a liquid is altogether confined to the metals, for many of which it has a considerable affinity, and forms compounds with them which are denominated *amalgams*. None of these are objects of pharmacy.

III. GASES.

GASES are aëriform fluids possessed of very different properties, but all agreeing in that peculiar kind of elasticity which constitutes aërial bodies.

1. CONSTITUTION OF GASES.

The particles of *gases*, like those of liquids, are moveable upon each other; but *gases* differ from liquids in possessing elasticity, or that power which allows them to be compressed into a smaller bulk; and by which, however large a portion of any gas contained in a vessel be taken away, the small portion which is left is enabled to expand so as to fill the vessel. The bulk of common air may be thus easily reduced or increased 3000 times; and indeed there does not appear to be any limit to expansion. These properties of airs depend on the repulsion which exists between their component particles; and the force of which, according to Newton, is always inversely as the distance of their centres

d

from each other. As gases contain a larger proportion of combined caloric than any other class of bodies, it is very probable that caloric is the cause of the repulsion which exists between their particles, or of their elasticity; and hence the addition of sensible heat to gases increases their elasticity, while the abstraction of it, or the application of cold, diminishes it. No degree of compression, nor abstraction of caloric, can alter the constitution of real gases or airs; but by these means, others and all the vapours can be reduced to the liquid or even the solid state.

Arrangement of the known gases according to their composition.¹

I. SIMPLE GASES.

- | | |
|------------------|--|
| 1. Oxygen gas. | 4. Oxymuriatic acid gas
(Chlorine.) |
| 2. Hydrogen gas. | 5. Sulphur vapour. |
| 3. Azotic gas. | 6. Iodine vapour. |

II. COMPOUND GASES.

a. Simple gases combined.

- | | |
|--|--|
| 7. Hydriodic acid. | 10. Nitrous oxide (deutoxide
of azote.) |
| 8. Hyperoxymuriatic acid
gas (protoxide of chlorine.) | 11. Muriatic acid gas. |
| 9. Nitrous gas (protoxide of
azote.) | 12. Steam. ² |
| | 13. Ammonia. |

b. Oxygen and a solid base.

- | | |
|------------------------|----------------------------|
| 14. Carbonic oxide. | 16. Sulphurous acid gas. |
| 15. Carbonic acid gas. | 17. Sulphuric acid vapour. |

c. Hydrogen and a solid base.

- | | |
|---------------------------------|--|
| 18. Cyanogen. | 21. Phosphureted hydrogen
gas, hydroguret of phos-
phorus. |
| 19. Olefiant gas. | 22. Bihydroguret of phos-
phorus. |
| 20. Carbureted hydrogen
gas. | |

d. Fluorine, chlorine, cyanogen, with a base.

- | | |
|------------------------|------------------------------------|
| 23. Fluoboric acid. | 25. Hydrocyanic (Prussic)
acid. |
| 24. Chlorocyanic acid. | 26. Chlorocarbonic acid. |

e. Triple or quadruple compound gases.

- | | |
|----------------------|------------------------------------|
| 27. Hydriodic ether. | 30. Muriatic ether. |
| 28. Chloric ether. | 31. Vapour of alcohol. |
| 29. Sulphuric ether. | 32. ——— of oil of turpen-
tine. |

All these gases are invisible, except the oxymuriatic acid and the hyperoxymuriatic acid, which have a yellowish green

¹ Thomson's Chemistry, 4th edit. iii. 487.

² Steam is not, in strict language, a gas; but a condensable vapour.

colour; but when gases of very different specific gravity are mixed together, they become in a certain degree visible. With respect to the specific gravity of gases, there is a greater difference between them under the same pressure, and at an equal temperature, than exists between liquid substances; a circumstance which must depend either on a difference of the repulsive force, or of the weight of the atoms in different gases.

A Table of the density and weight of 100 cubic inches of the gases at the temperature of 60°, and a barometric pressure of 30°.

	Specific Gravity.	Weight of 100 cubic Inches.		Specific Gravity.	Weight of 100 cubic Inches.
Air - - -	1.000	30.5	Olefant Gas -	0.974	29.720
Oxygen - -	1.111	33.888	Carbureted hydrogen	0.555	16.99
Hydrogen -	0.0694	2.117	Hydroguret of Phos-	0.9022	27.517
Azote - - -	0.9722	29.652	phorus - - -		
Chlorine - -	2.500	76.250	Bi-hydroguret of	0.9716	29.634
Sulphur Vapour -	1.111	33.888	Phosphorus - -		
Vapour of Iodine -	8.678	264.679	Fluoboric Acid -	2.3709	72.312
Hydriodic Acid -	4.375	133.434	Chlorocyanic acid va-	2.152	65.636
Protoxide of Chlorine	2.440	74.420	pour - - - -		
Protoxide of Azote -	1.5278	46.598	Hydrocyanic acid va-	0.9368	28.572
Deutoxide of Azote	1.0416	31.769	pour - - - -		
Muriatic Acid -	1.284	39.162	Chlorocarbonic Acid	3.472	105.896
Steam - - -	0.625	19.062	Hydriodic Ether -	5.475	156.987
Ammonia - -	0.590	18.000	Chloric Ether - -	3.474	105.957
Carbonic Oxide -	0.9722	29.652	Sulphuric ether vapour	2.586	78.873
Carbonic Acid -	1.527	46.373	Muriatic Ether -	2.219	67.679
Sulphurous Acid	2.222	67.771	Alcohol Vapour -	1.6133	49.206
Sulphuric Acid -	2.777	84.698	Oil of Turpentine ?	5.013	152.896
Cyanogen - -	1.804	55.028	Vapour - - - -		

Water is a constituent of almost every gaseous body; and the quantity of it contained in each depends upon the bulk, not the density, of the gas. It also appears probable, that the weight of it contained in 100 inches of all gases under the same pressure, and at the same temperature, is very nearly the same. It can be separated, in a great degree, by very dry alkalies, lime, and other matters which have a powerful attraction for water; but the whole of the moisture cannot be absorbed by these substances; and it does not appear that gases cannot exist independent of the presence of water. The quantity present in any gas is regulated, in a great degree, by the temperature: for, if this be high, a much larger proportion of moisture can be retained in the elastic form; but in a low temperature it is deposited.

Vapours differ from gases in several particulars. Their "elasticity does not increase as the pressure, like that of gases;" they can be condensed by pressure, and by the abstraction of caloric, into liquids. By the latter mode, also, some of those bodies which are regarded as real gases, such as ammonia and oxymuriatic gas, are reduced to the liquid form. The elasticity of the majority of vapours is sensible at a high temperature only; but some become sensibly elastic at the common temperature.

2. OF THE MIXTURE OF GASES WITH GASES.

1. Gases may be mixed together in the same manner as liquids, and with nearly similar results. Some never intimately combine, or are merely mechanically mingled, while others unite closely, and form new chemical compounds, possessing properties very different from those of their components.

TABLE of gases which may be mixed together without any apparent change in their state.

i. Gases that may be mixed, but which do not combine.

Oxygen with fluoboric, fluosilic, and carbonic acid gases.
Hydrogen with muriatic acid, fluoboric acid, and fluosilic acid; carbonic oxide, olefiant gas, carbureted hydrogen, phosphureted hydrogen, sulphureted hydrogen, and ammoniacal gas.

Azote, with almost all the other gases.

Fluoboric acid and fluosilic acid, with all the other gases.

ii. Gases which mix without any change, but may be made to combine.

Oxygen with oxymuriatic acid, iodine, hydrogen, azote, carbonic oxide, sulphurous acid, and nitrous oxide.

Hydrogen with oxymuriatic acid, iodine, and azote.

iii. Gases which mix without change, but may be made to decompose each other.

Oxygen with carbureted hydrogen, bihydroguret of phosphorous, olefiant gas, sulphureted hydrogen, cyanogen, and ammonia.

Hydrogen with carbonic acid, nitrous gas, nitrous oxide, and sulphurous acid.

Although these gases, when simply mixed, do not chemically combine, or act on each other, yet the mixtures, even independent of agitation, are homogeneous compounds, or the gases do not arrange themselves according to their gravities, but are all equally diffused throughout the mixtures, and when once mixed never afterwards separate. The bulk also, after mixture, is exactly equal to the sum of the bulks of the

gases which have been mixed; or each gas occupies the same space as when separate; and the specific gravity of the mixture is exactly the mean of that of the gases mixed. Hence the mixture of these gases appears to be a species of combination, similar to that which takes place in mixing together vinegar and water, or similar liquids.

Vapours and gases unite in nearly the same manner as gases and gases; and this combination enables the vapour to sustain the pressure of the incumbent atmosphere, without being condensed, which it could not otherwise support. They are also retained together by a species of affinity, sufficient to cause their intimate and uniform mixture, but not strong enough to produce chemical combination.

2. Of the gaseous bodies which chemically unite when they are mixed, "some combine in all circumstances by mere mixture; others unite only in particular states."

TABLE of the gases which unite by simple mixture, and of the products formed by the combinations.

Names of gases.	Products.
Oxygen with nitrous gas	{ Nitrous acid. Nitric acid.
Ammoniacal gas with vapour	Liquid ammonia.
-----muriatic acid	Muriate of ammonia.
-----fluoboric acid	Fluoborate of ammonia.
-----carbonic acid	Carbonate of ammonia.
-----sulphurous acid	Sulphite of ammonia.
-----sulphureted	{ Hydrosulphuret of ammonia.
hydrogen	

The two first of these products are vapours, the third is a liquid, and the rest are solid bodies.

a. Oxygen and nitrous acid unite in two different proportions; or 100 volumes of oxygen gas is capable of uniting with 133, and also with 200 volumes of nitrous gas. The first proportions produce nitric acid, which, as nitrous gas is a compound of $66\frac{2}{3}$ volumes of azote, and $66\frac{2}{3}$ of oxygen, therefore, appears to be a compound of $166\frac{2}{3}$ volumes of oxygen combined with $66\frac{2}{3}$ of azote; the second produce nitrous acid, or nitric acid saturated with nitrous gas, which appears on the same principles to be a compound of 200 volumes of oxygen united to 100 of azote. It is, however, probable, that these gases will combine in different proportions from the above, and produce nitric acid, containing various proportions of nitrous gas in solution. The immediate effect of their combination is the formation of a yellow-coloured vapour.

- b. *Ammoniacal gas* and *aqueous vapour* combine the moment they are brought into contact, and are condensed to a liquid; but the exact proportions are unknown.
- c. *Ammoniacal gas* and *muriatic acid gas* unite when equal volumes of each are brought into contact; and the result of the mixture is a mutual condensation into a white powder, or muriate of ammonia. If 100 cubic inches of muriatic acid gas, therefore, weigh 59·80, and the same bulk of ammoniacal gas 18·67 grains troy, muriate of ammonia must be a compound of 3 parts of muriatic acid by weight, united to 1 part of ammonia.
- d. *Ammoniacal gas* and *carbonic acid* unite in equal volumes, and condense into a solid salt, which is carbonate of ammonia. The combinations of this gas with the *fluoboric acid* are more varied, while with *sulphurous acid* and sulphureted hydrogen it also unites in equal volumes, and forms solid compounds.

TABLE of gases which mix without chemically combining, but may be made to combine; and of the products formed by the combinations.

Names of gases.	Products.
Oxygen with hydrogen	Water.
_____ carbonic oxide	Carbonic acid.
_____ azotic gas	Nitric acid.
_____ muriatic acid	Oxymuriatic acid?
_____ oxymuriatic acid....	Hyperoxymuriatic acid?
_____ sulphurous acid	Sulphuric acid.
_____ nitrous oxide	Nitric acid.

- a. The two first combinations may be effected by combustion, and the third by electricity. It has been supposed that the heat in these cases acts indirectly only, and produces the combination by forcibly expanding one portion of the gas, and thence producing a sudden compression in the neighbouring portions, so that some of the atoms of the two gases, being brought within the sphere of action of the attraction of affinity, combine; while the caloric evolved by this union occasioning the same expansion to be constantly renewed, the whole gaseous mixture is by degrees combined. This theory is confirmed by the experiments of Biot, which proved that oxygen and hydrogen gases can be made to combine by simple pressure.
- b. The combination of *oxygen gas* with *muriatic* and *oxymuriatic acids* has been rendered at least problematical by

the experiments of Sir H. Davy: but as the question is still *sub judice*, I have retained the old opinions.¹

c. *Oxygen gas* and *sulphurous acid gas* probably combine when simply mixed together, but the fact has not been ascertained in a decisive manner. They undoubtedly combine in a red heat: it is, however, probable that the combination is not direct, but that a portion of the sulphur is first separated, and then enters into combustion.

All these gases suffer condensation when they combine. The following TABLE exhibits at one view the principal facts connected with their combinations.²

Constituent gases.	Proportions.	Specific gravity of each.	Compounds produced.	Calculated gravity of the compound.	Real specific gravity.	Bulk of the compound.	Condensation.
Oxygen - - -	59.8	0.675*	Steam.	0.287	0.700	41.	59.
Hydrogen - - -	10.	0.065					
Oxygen - - -	31.	1.103	Carbonic acid.	0.997	1.500	66.4	33.6
Carb. oxide - - -	69.	0.956					
Oxygen - - -	70.23	1.103	Nitric acid.	1.062	2.427	43.7	56.3
Azote - - -	29.77	0.978					
Oxygen - - -	24.3	1.103	Sulphuric acid.	1.970			
Sulphurous acid -	147.0	2.265					
Oxygen - - -	17.5	1.103	Nitric acid.	1.292	2.427	53.	47.†
Nitrous oxide - -	158.	1.603					
Oxygen - - -	78.	1.103	Nitric acid.	1.394	2.427	57.4	42.6†
Nitrous acid - -	158.	1.603					

* The temperature at which the gravity in this case is taken is 212°; all the rest are taken at 60°.

† The condensation stated in these two columns is hypothetical.

TABLE of the principal gases which mutually decompose each other when mixed together.

Oxygen withPhosphureted hydrogen.
 Oxymuriatic acid withAmmonia.
Phosphureted hydrogen.
Carbureted hydrogen.
Olefiant gas.
Sulphureted hydrogen.

¹ I am the more induced to adhere to the old opinions, from the convincing proofs of their accuracy, which have been lately advanced by my friend Dr. Murray. Vide *Experiments on Muriatic Acid Gas*, &c. *Edinburgh Transactions*, 1818.

² This Table is copied from that drawn up by Dr. Thomson (*Syst. of Chemistry*, 4th edit. iii. 477.); but I have left out the columns relating to the combination of oxygen with the muriatic and oxymuriatic acids, for the reasons already stated.

Oxymuriatic acid withNitrous gas.
 Sulphureted hydrogen with ...Nitrous gas.
 ————— ...Sulphurous acid.

All these gases, except the oxygen and hydrogen, are compounds. The three first decompositions are attended with combustion.

- a. *Phosphureted hydrogen with oxygen.* The first of these gases may be regarded as phosphorus dissolved in hydrogen; and consequently in that state which enables oxygen to act upon it at the ordinary temperature of the atmosphere. When the proportion of phosphorus is considerable, the combustion is extremely brilliant, and the caloric evolved is sufficient to set fire to the hydrogen. The products, when the combustion is incomplete, are water, phosphorous acid, and hypophosphorous acid; but when it is complete, they are water and phosphoric acid.
- b. *Oxymuriatic acid and ammonia* when brought into contact, excite spontaneous combustion; but none of the azote, which forms one constituent of the ammonia, enters into combination with the oxygen.
- c. *Phosphureted hydrogen gas*, when mixed with oxymuriatic gas, burns, and exhibits a lively combustion. Both the components of the first gas combine with the oxygen, affording as products water and phosphoric acid, while common muriatic acid is evolved.
- d. *Oxymuriatic acid gas*, when mixed with the heavy inflammable gases, does not occasion combustion, but slow and imperceptible decomposition takes place; the constituents of each gas uniting with the oxygen, and forming products corresponding to those of combustion. With nitrous gas it is brought to the state of common muriatic acid; while the nitrous gas is converted into nitric acid. The requisite proportions, according to Humboldt¹, are equal bulks of each gas.
- e. *Sulphureted hydrogen gas and nitrous gas* mixed together in a dry state suffer spontaneous decomposition, sulphur is deposited, and nitrous oxide, ammonia, and water, are produced.

TABLE of gases which mix without spontaneous decomposition, but which may be made to decompose each other by peculiar treatment.

Oxygen with sulphureted hydrogen.
 ————— carbureted hydrogen.
 ————— olefiant gas.

¹ Ann. de Chimie, tome xxviii. p. 142.

Oxygen with vapour of ether.

————— alcohol.

Nitrous oxide with hydrogen.

————— phosphureted hydrogen.

————— sulphureted hydrogen.

————— carbonic oxide.

Nitrous oxide with carbureted hydrogen.

————— olefiant gas.

————— vapour of ether.

————— alcohol.

————— sulphurous acid.

Nitric acid with hydrogen, and probably all the preceding combustible gases and vapours.

————— sulphurous acid.

Nitrous gas with hydrogen.

————— sulphurous acid.

Hydrogen with sulphurous acid.

————— carbonic acid.

Vapour of water with carbureted hydrogen.

————— olefiant gas.

Some of these decompositions are produced by combustion, and are instantaneous; others take place without combustion, and are consequently very slow.

Oxygen and sulphureted hydrogen gases when mixed together do not suffer any change; "but if the mixture be made to approach an ignited body, combustion immediately takes place, and the products vary according to the proportion of the gases mixed." In all cases a great proportion of the sulphur is deposited, and some sulphurous acid is formed, owing to the caloric evolved by the combustion of the hydrogen setting fire to a portion of the sulphur.

If *oxygen gas*, in a small proportion, and *carbureted hydrogen*, or *oxygen and olefiant gas*, be exploded together, charcoal is deposited, and water and carbonic acid produced; beside which an inflammable gas, named by Berthollet *oxycarbureted hydrogen*, remains, occupying more than double the space of the original gases. But if the proportion of oxygen be large, that is, twice the bulk of the carbureted hydrogen, and three times that of the olefiant gas, these two gases are completely consumed, and the products are water and carbonic acid.

The *vapours of ether* and of *alcohol*, detonate when certain proportions are mixed with common air, or rather with the oxygen it contains; and the products are carbonic acid and water: the quantity of the former being very considerable when the vapour fired is that of alcohol. If the proportion

of the ethereal vapour be one cubic inch, which should weigh 0·7 grains, and that of the oxygen 6·8 inches weighing 2·3 grains, the products will be 4·6 inches of carbonic acid, and a portion of water, resulting from the union of the remaining 2·2 inches of oxygen with 0·10 of hydrogen.

The following TABLE shows the quantity of oxygen necessary for decomposing 100 inches of each of the above gases.

100 Measures of	Measures of oxygen.	100 Measures of	Measures of oxygen.
Sulphureted hydrogen	- 75	Vapour of ether	- - - 680
Carbureted hydrogen	- 200	alcohol	- - - 680 ¹
Olefiant gas	- - - 200		

When 100 measures of *nitrous oxide* are mixed with 100 of *hydrogen*, and fired by the electric spark, a complete combustion of the hydrogen and decomposition of the nitrous oxide take place, and water and azote are produced. The superior affinity of the hydrogen over azote is in this case aided by the caloric evolved during the combustion of the former gas.

One measure of *phosphureted hydrogen*, and three measures of nitrous oxide, are completely decomposed when exploded by the electric spark, producing water and phosphoric acid, and leaving three measures of pure azote. In this case the proportion of nitrous oxide is sufficient to combine with both the components of the phosphureted hydrogen gas. In the same manner *sulphureted hydrogen gas* is acted on by *nitrous oxide*; and the products of the detonation are water, sulphuric acid, and azote.

When a mixture of *olefiant gas* and *nitrous oxide* is detonated, the products are modified by the quantity of the latter gas employed; when this is large, the constituents of the inflammable gas are both saturated with oxygen, and water, carbonic acid, and azote, are produced; but when a smaller proportion is used, an inflammable gas remains.

In all cases of the combustion of nitrous oxide with inflammable gases the phenomena are analogous to their combustion in oxygen; and the same is the case when mixtures of nitrous gas and the combustible gases are fired by being passed through a red-hot tube. Nitrous gas, however, does not detonate with, nor decompose any of the combustible gases which have been just considered; but when moist iron is placed in contact with nitrous gas, the hydrogen evolved by the decomposition of the water for the oxidizement of the iron, decomposes the nitrous gas, converting it into nitrous oxide, and forming ammonia.

¹ Thomson's Chemistry, 4th edit. iii. 496.

The other cases of decomposition enumerated in the table are slowly produced by the continued action of elasticity, without any combustion taking place.

The combinations of gases with gases are not immediately effected for the purposes of Pharmacy, but several of them occur during many of the operations for the preparation of the saline and metallic compounds; and therefore require to be known and understood for comprehending the theory of these operations.

2. OF THE COMBINATION OF GASES WITH LIQUIDS.

Water is the only liquid the action of which upon the gases has been accurately examined. In its ordinary state it contains in solution a considerable portion of atmospheric air, which can be separated from it by boiling: and it is then capable of re-absorbing air, and any other gaseous fluid with which it may come in contact. All gases, however, are not equally absorbable; some being taken up in great quantity, and others only in a very small proportion.

TABLE of gases which are but little absorbable by water, placed in the order of their absorption, beginning with the least absorbable.

- | | |
|---------------------------|---------------------------|
| 1. Azotic gas. | 7. Oxygen gas. |
| 2. Hydrogen gas. | 8. Nitrous gas. |
| 3. Arsenical hydrogen. | 9. Olefiant gas. |
| 4. Carbureted hydrogen. | 10. Nitrous oxide. |
| 5. Carbonic oxide. | 11. Carbonic acid. |
| 6. Phosphureted hydrogen. | 12. Sulphureted hydrogen. |

The quantity of any gas absorbed by water is very much increased by pressure; but by diminishing this pressure the gas again separates in its elastic form. Temperature also regulates the quantity, which diminishes as the temperature increases, owing to every additional increment of caloric augmenting the elasticity of the aëriiform fluid. Thus Dr. Henry found that 100 inches of water at 55° absorbed 108 inches of carbonic acid, while at 85° it absorbed only 84 inches.

When water is pure, and the pressure and temperature the same, it then "absorbs a determinate quantity of every individual gas."

TABLE, exhibiting the bulk of each of the foregoing gases absorbed by 100 cubic inches of water at 60°, according to the experiments of Mr. Dalton, Dr. Henry, and M. Saussure.¹

Names of Gases.	Bulk absorbed by 100 cubic inches of water.		
	DALTON.	HENRY.	SAUSSURE.
Carbonic acid - - - -	100	108	106
Sulphureted hydrogen -	100	106	253
Nitrous oxide - - - -	100	86	76
Olefiant gas - - - -	12.5	—	15.3
Nitrous gas - - - -	3.7	5.	—
Oxygen gas - - - -	3.7	3.7	6.5
Phosphureted hydrogen -	—	2.14	—
Carbureted hydrogen -	3.7	1.4	5.1
Azotic gas - - - -	1.56	1.53	4.1
Hydrogen - - - -	1.56	1.61	4.6
Carbonic oxide - - - -	1.56	2.01	6.2

From this table, it appears that water absorbs its own bulk, or rather more, of the gases in the first compartment; one-eighth of its bulk of that in the second; one-twenty-seventh of those in the third, and one-sixty-fourth of those in the fourth; and the absorption is in the direct ratio of the densities of the gases.

With regard to pressure, water of the same temperature always takes up the *same bulk* of each gas, whatever be the density of the gas; and therefore, by increasing the pressure sufficiently, water may be made to absorb any quantity of gas. Thus, twice its bulk of carbonic acid will be absorbed under an additional pressure of 30 inches of mercury; three times its bulk under a pressure of 60 inches, and so on. A fact which has been applied to practice, in the manufacture of aerated soda-water, on a great scale. From this circumstance it would appear that the absorbed gas still retains its elasticity; yet it is probable that a chemical attraction is exerted between the particles of the water and those of the gas, and it is taken up until the repulsion between the particles of the absorbed gas just balances the affinity of the water for them. Owing, however, to the weak affinity exerted between the gas and the

¹ Thomson's Chemistry, 5th edit. iii. 58.

water, if a quantity of water fully impregnated with any gas, as carbonic acid, for example, be exposed to the atmosphere, or any other gaseous body, the greater part of the absorbed gas escapes from the water and mixes with the superincumbent air; and, therefore, to preserve the impregnation complete, the aerated water must be preserved in well-stopped bottles; or under an atmosphere of the same gas it contains.

Such are the principal circumstances connected with the absorption of the less absorbable gases: those which are more absorbable appear to belong to the class of *acids* and *alkalies*.

TABLE of the very absorbable gases hitherto examined, placed in the inverse order of their absorbability, with the numbers of measures of each absorbed by one measure of pure water.¹

Names of gases.	Measures absorbed.
Oxymuriatic acid gas (chlorine) - - -	2
Cyanogen - - - - -	4½
Sulphurous acid - - - - -	43.78
Fluosilic acid - - - - -	363+
Muriatic acid - - - - -	516
Fluoboric acid - - - - -	700
Ammoniacal - - - - -	780

The water when saturated with these gases undergoes an increase of bulk. The following table exhibits this change, supposing the original bulk to have been 1.²

Saturated with	Cubic inches.
Oxymuriatic acid gas (chlorine) - - -	1.002+
Sulphurous acid - - - - -	1.040
Fluosilic acid - - - - -	—
Muriatic acid - - - - -	1.500
Ammoniacal - - - - -	1.666

The absorption of these gases is the consequence of the exertion of an affinity between them and water; but in every respect the circumstances attending it are exactly the same as those attending the absorption of the former class of gases; except that "most of the gases belonging to the first class experience an expansion when absorbed; while all those of the second undergo a condensation, their affinity for water being greater than their elasticity."

With regard to the absorption of gases by other liquids, scarcely any very decisive experiments have been made.

3. OF THE COMBINATION OF GASES WITH SOLIDS.

From the difference which exists between the constitutions of gases and solids, their combination appears to be opposed by

¹ Thomson's Chemistry, 5th edit. iii. 69.

² Ibid. 68.

the elasticity of the former and the cohesion of the latter ; but, nevertheless, under proper circumstances, both the simple and the compound gases combine with solids.

The simple gases are *oxygen*, *hydrogen*, *azote*. Of these oxygen combines with all the known simple solids ; hydrogen requires that the solids be brought into a fluid state before it combines with them ; and azote combines with one solid only, which is carbon.

a. Oxygen gas unites with carbon in two proportions, and forms *carbonic acid*, and *carbonic oxide*, which are gaseous fluids. Experiment has demonstrated that carbonic acid is composed of 27.27 parts of carbon and 72.73 of oxygen : hence, according to the theory of Dalton, an atom of it must consist of two atoms of oxygen and one of carbon. *Carbonic oxide* is composed of 41 parts by weight of oxygen and 28 of carbon ; or of one atom of oxygen and one of carbon. Oxygen combines with boron in one proportion only, forming *boracic acid*, which is a compound of one atom of boron and two atoms of oxygen, or 100 parts of boron and 228.57 of oxygen.

With phosphorus, oxygen unites in three proportions, and forms *hypophosphorous acid*, *phosphorous acid*, and *phosphoric acid*, which are all solid substances. The proportions of the constituents of these three compounds are the following : *hypophosphorous acid* consists of 100 of phosphorus and 66.6 of oxygen, or one atom of phosphorus and one of oxygen : *phosphorous acid* of 100 of phosphorus and 133.3 of oxygen, or of one atom of phosphorus and two of oxygen ; and *phosphoric acid* of 100 of phosphorus and 200 of oxygen, or one atom of phosphorus and three of oxygen.

Oxygen combines with sulphur in the same manner, and forms *hyposulphurous acid*, *sulphurous acid*, and *sulphuric acid* ; the first of which is supposed to be a solid, the second and third are gases. According to Dalton's theory, the constituents of *hyposulphurous acid* are one atom of sulphur and one of oxygen ; or of 100 parts of sulphur and 50 of oxygen ; one of *sulphurous acid*, one of sulphur and two of oxygen, or 100 of sulphur and 100 of oxygen : while *sulphuric acid*, which is found by experiment to be composed of 150 parts by weight of oxygen and 100 of sulphur, is formed by the union of one atom of sulphur to three atoms of oxygen. The oxygen in these compounds is much more loosely combined than in the preceding ; and hence the greater facility with which they are decomposed by combustibles.

Oxygen unites readily with the *metals*, forming solid compounds. In them the oxygen is condensed, while the cohesion of the metallic particles is merely weakened, but not overcome.

It has been supposed that the metals combine with determinate proportions only of oxygen, that there are no intermediate combinations, and that in general there are only two degrees of metallic oxidizement. There is reason, however, to believe with Berthollet, that the proportions are indefinite from the commencement to the highest degree of oxidizement of which any metal is susceptible, or to complete saturation; and in cases where determinate proportions are observed, these are owing to peculiar circumstances, which limit the combination, and "which in general being uniform, give rise to an invariable proportion." Thus, if the oxidizement of a metal takes place at its melting point, or at its vaporific point, these being uniform, the oxide will consequently be so, or the same determinate proportion will be observed in the combination. The compounds formed by the combination of oxygen with the metals have a powerful action on the animal economy, and are consequently very important objects of pharmacy. In this state metals become, also, capable of combining with acids, and acquire still greater activity; and as the degree of oxidizement varies, so the combination of the oxide in these different states with the same acid forms compounds differing from each other, and exerting various degrees of medicinal power.

b. Hydrogen has a considerable affinity for the simple combustibles; but they do not combine unless the cohesive force, which keeps together the particles of the solid, be overcome, or the hydrogen be exhibited in a nascent state; and, therefore, it is chiefly by the decomposition of water that these combinations are effected. Owing to the great elasticity of hydrogen gas, all the known combinations of it with the simple combustibles, except one, are gases.

Hydrogen unites with *carbon* in three proportions, constituting *olefiant gas*, which is composed of one atom of carbon and one of hydrogen; *carbureted hydrogen*, composed of two atoms of hydrogen and one of carbon; and *ether*, composed of 6 atoms of hydrogen, 5 of carbon, and 1 of oxygen. The first is the most intimate compound of the three, and carbureted hydrogen the next; for neither of these is affected by a red heat; whereas ether is decomposed, and converted into olefiant gas, carbureted hydrogen, and charcoal.

"Sulphureted hydrogen is the most intimate of the combinations of *sulphur* and hydrogen. A red heat does not decompose it." It is commonly formed by the "decomposition of water by the compound agency of an acid and a metal united to sulphur." In this case no obstacle is raised to the combination of the hydrogen, which is nascent, by the attraction of cohesion, the sulphur being just separated from the metal.

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

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

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

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

SECTION III.

PHARMACEUTICAL OPERATIONS AND APPARATUS.

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

- I. *Operations which are purely mechanical.*
- II. *Operations which are performed by chemical powers and agents.*

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

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

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

I. PHARMACEUTICAL OPERATIONS PURELY MECHANICAL.

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

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

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

A pound (<i>libra</i>), lb	} contains {	Twelve ounces.
An ounce (<i>uncia</i>), ℥		Eight drachms.
A drachm (<i>drachma</i>), ℥		Three scruples.
A scruple (<i>scrupulus</i>), ℥		Twenty grains.
A grain (<i>grana</i>), gr.		

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

Apothecaries' weight.

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

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

Avoirdupois weight.

Pounds.	Ounces.	Drachms.	Grains.
1	= 16	= 256	= 7000
	1	= 16	= 437.5
		1	= 27.975

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

A gallon (<i>congius</i>), cong.	} contains {	Eight pints.
A pint (<i>octarius</i>), o		Sixteen fluid ounces.
A fluid ounce (<i>fluid uncia</i>), f̄3		Eight fluid drachms.
A fluid drachm (<i>fluid drachma</i>), f̄3		Sixty minims.
A minim (<i>minima</i>), m		

Table of the proportions of the wine gallon.

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

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

For measuring liquids graduated glass measures of different sizes are to be preferred; (PL. i. fig. 8, 9.) and for quantities under five minims a slender graduated glass tube, (PL. i. fig. 10.) open at both ends, is to be employed. When this tube is used, the graduated end is to be inserted into the liquid to be measured, down to the mark indicative of the quantity required; and the upper end being then closely covered by the finger, it is removed, retaining the proper quantity of liquid, which again drops from it on raising the finger from the upper end. In extemporaneous prescription the measures of a table-spoonful and a tea-spoonful are used when great accuracy is

not required; the former being supposed to be equal to half a fluid ounce, the latter to a fluid drachm.

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

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

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

¹ Lavoisier's *Elements of Chemistry*, — Trans. 376.

² Nicholson's *Journal*, 410. i. 110.

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

In ascertaining specific gravity the substances should be brought by calculation to the temperature of 55°, if the thermometer be above or below that point at the time of performing the experiments; and the gravities should always be expressed according to their relation to distilled water. Although this is the method generally employed in philosophical and pharmaceutical operations, yet it is necessary to observe, that the strength of spirits, according to the Excise laws in this country, is estimated by the proportion they contain of a standard spirit, termed hydrometer proof, which consists of 40 parts of pure alcohol and 51 of water. Clarke's hydrometer, which is the one employed by the Excise, loaded with the proper weights, sinks to the mark indicating *proof* in spirits of the specific gravity 0.920, at a temperature of 60°. The strength of spirits stronger than proof, or *over proof*, is ascertained by the bulk of water required to reduce a given bulk of the spirits to the specific gravity denominated proof, on Clarke's hydrometer; and the strength of weaker spirits, or *under proof*, is estimated by the quantity of water it would be necessary to abstract to bring the spirits up to proof. Thus, if 20 gallons of the spirit require the addition of one gallon of water to bring it to proof, the spirit is said to be *one to twenty over proof*; and if, from the same quantity of spirit, one gallon of water must be abstracted to bring it to proof, it is said to be *one in twenty under proof*; and so on.

b. *Of the mechanical division of bodies.*

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

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

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

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

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

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

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

Vegetable matters require to be dried before they can be pulverized; and wood, roots, and barks should be previously cut, chipped, or rasped. When roots are very fibrous, as those of ginger, for example, it is advisable to cut them diagonally, which prevents the powders from being full of hair-like filaments. Resins and gum resins, which soften in a moderate temperature, or in warm weather, should be powdered in cold weather, and only gently beaten to prevent them from running into a paste instead of forming a powder; and when the powdered substance is intended to be dissolved in any menstruum, except a pure alkali, the pulverization is much facilitated by mixing them with a portion of clean well washed white sand. The pulverization of camphor is assisted by the addition of a few drops of alcohol; sugar is the best addition to aromatic oily substances, as nutmegs, mace, &c.; and to the emulsive seeds some dry powder must be added, without which they cannot be reduced to powder. Metals which are scarcely brittle enough to be powdered, and yet are too soft to be filed, as zinc, for instance, "may be powdered while hot in a heated iron mortar, or may be rendered brittle by alloying them with a small quantity of mercury¹;" but as metals are not required to be reduced to the state of very fine powder for pharmaceutical purposes, these processes are seldom performed.

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

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

¹ Lavoisier's Chemistry,—Trans. 437.

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

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

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

MECHANICAL SEPARATION.

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

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

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

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

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

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

glass rods be arranged round the inside, so as to form an unequal surface for the paper to rest upon.

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

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

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

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

For expressing the unctuous seeds, in order to obtain the oil they contain, iron plates are employed; and the bruised seeds

should be previously exposed in a bag to the steam of boiling water.

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

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

II. CHEMICAL OPERATIONS.

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

- a. Operations which produce chemical changes in bodies, separating the constituents, without any obvious decomposition.
- b. Operations in which changes are produced by the chemical action of one set of bodies upon another, or attended with obvious decomposition.
- c. Operations in which the oxygenization and the disoxygenization of bodies are effected by means of a very high temperature.

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

1. By caloric - - - - -

Liquefaction.

Fusion.

Evaporation.

Exsiccation.

Distillation.

Rectification.

Dephlegmation.

Sublimation.

2. By water - - - - -

Solution.

Lixiviation.

Maceration.

Digestion.

Infusion.

Decoction.

Extraction.

3. By other chemical agents

Coagulation.

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

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

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

Fusion is usually performed in crucibles, the best of which are made of very pure clay, or potter's earth. Those formed of common clay with calcareous or siliceous earth are very fusible. The Hessian crucibles are composed of clay and sand, and when good, stand the fire very well; as do also Wedge-

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

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

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

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

with the fluid, or the degree of heat at which the process is conducted. As the fluid which is dissipated is entirely lost, and sacrificed for the sake of the fixed substance with which it was combined, evaporation is only employed where the liquid is of little value, such as water; but where a solid is to be recovered from a more valuable liquid, as alcohol, for instance, the process of distillation is employed.

For small processes, very good evaporating dishes are made of the bottoms of broken retorts and matrasses, which may be cut smooth round the edges by means of a hot iron or ring, pl. iii. fig. 8. and thus converted into semiglobular¹ basins. The best evaporating dishes, however, are those of biscuit porcelain made by Wedgewood, and sold in assortments, the largest of which is capable of holding eight or ten pints. They are flat-bottomed, shallow vessels, with a lip in the upper edge, fig. 1. pl. iii. glazed in the inside; and thin, but of a dense hard texture. They will bear to be heated to the boiling point over a clear hot fire; but are apt to crack when a flame is allowed to play on them, or when the liquor is boiled to dryness, at the moment the last drop of fluid is expelled, unless the fire be much lowered.

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

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

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

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

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

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

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

For the preparation of alcohol, and of distilled waters, the

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

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

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

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

In chemical operations, when the gases which are separated during any process are to be preserved, the pneumatic trough, fig. 1. pl. v. is attached to Woulfe's apparatus. The construction of the trough differs according to the nature of the

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

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

Sublimation is a species of distillation, in which the product of the volatilization is condensed in a solid form; but as this condensation takes place at a higher temperature than that of watery vapour, a much more simple apparatus is required. The process is conducted sometimes in a crucible, with a cone of paper or another crucible inverted over it, in which the product is condensed; and as in this case it is light and spongy, it was formerly denominated *flowers*. For other

matters which are less volatile a cucurbit and capital, or a flask, or phial, are employed, and sunk about two-thirds in a sand-bath. The product in these cases is generally solid, and is denominated a *sublimate*.

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

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

Although a liquid be saturated with one solid, yet it may be still capable of dissolving a portion of another, and even of a third when saturated with the second; until it be combined with, or hold in solution, three, four, or five different bodies

at the same time. The liquid, indeed, in this case does not dissolve so large a portion of any of the substances; but sometimes, from the mutual affinities which the substances exert, the whole proportion of solid matter dissolved is very much increased.

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

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

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

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

Digestion is an operation similar to maceration, but the power of the fluid is aided by a gentle degree of heat. It is usually performed in a glass matrass, and the evaporation of the liquid impeded by stopping the mouth of the matrass slightly, with a plug of tow, or tying over it a piece of wet bladder perforated with small holes. When the menstruum is valuable, as alcohol, for instance, another matrass, with a smaller mouth, may be inverted over the former, and the joinings secured by a piece of wet bladder; or, what is perhaps preferable, a long open glass tube may be luted to the mouth of the matrass containing the materials. By these means, any part of the liquor which is resolved into steam by the heat, is condensed, and conveyed back upon the materials. The matrass may be heated

either by a common fire, a water-bath, or a sand-bath; and when either of the latter are used, it should not be sunk deeper in the water, or the sand, than the portion that is filled. The process has been denominated *circulation*, when the condensed vapours are returned upon the ingredients.

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

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

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

Extraction is the result of either infusion or decoction: if the liquor obtained by either of those processes be subjected to evaporation, the watery part is dissipated, and the part extracted by them is obtained in the solid form, and denominated

an *extract*. The same objections may be urged against this species of preparation as were stated under *Decoction*.

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

3. *Changes produced by chemical agents.*

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

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

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

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

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

Precipitation is an operation also in which decomposition takes place, a solid substance being thrown down from a liquid in which it was held in solution, by the chemical action of

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

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

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

Precipitation is intended to separate solids from solutions in which they are contained; to produce new combinations, which cannot readily be formed by the direct union of their constituents; and to purify solutions from precipitable impurities. A knowledge of those substances which produce precipitation is also of much importance, in extemporaneous prescription; to prevent the virtues of remedies from being

destroyed by improper combinations. The following Tables of Precipitants are extracted from those drawn up by Dr. Thomson.¹

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

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

Crystallization, although it can scarcely be regarded as a

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

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

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

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

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

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

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

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

¹ *Journal de Physique*, lv, 300.

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

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

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

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

FERMENTATIONS.

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

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

Vinous fermentation. All vegetable substances containing saccharine matter, and a peculiar glutinous principle analogous

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

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

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

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

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

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

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

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

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

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

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

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

Furnaces differ in construction, according to the particular

¹ *System of Chemistry*, iv. 465.

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

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

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

covers the inside of the furnace, and the cavity assumes an elliptical form.

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

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

With regard to *fuels*, the best are undoubtedly charcoal and coak, or a mixture of these. The advantages of *charcoal* are its kindling readily, burning with a strong clear heat in a small draught, without running into slag, choking the grate, or melting the walls of the furnace; and owing to its containing only matter which is extremely combustible, the flues or chimneys never collect soot or other foulnesses. The

chief objection to charcoal is its great expense. *Coak* is much less expensive; but as it contains a mixture of earths and metallic oxides, it is apt in an intense heat to run together into a tough cohesive slag, which adheres to the walls of the furnace, and to the sides of crucibles, choking up the grate, and of course preventing the proper draught for carrying on the combustion. These disadvantages, however, are remedied by mixing it with an equal bulk of charcoal; and these united form the best fuel when an intense heat is required.

The pharmaceutical operations (usually performed in furnaces) are —

Fusion.

Evaporation.

Distillation.

Sublimation.

The oxidizement of metals.

The deoxidizement or reduction of metals.

The four first of these have been already described.

Oxidizement of metals. This term signifies that process by which metals are converted into oxides, by absorbing oxygen from the air, when exposed to a certain degree of heat. The disengagement of the caloric and light which oxygen gas contains, by the solidification of the oxygen in the oxide, is scarcely perceptible when the operation is conducted in atmospheric air; but if the oxidizement takes place in oxygen gas, it is rapidly effected, and caloric and light are very evidently extricated. This mode, however, of oxidizing metals is employed in small experiments only; but in all the processes of the laboratory for procuring oxides by the aid of heat, common air yields the oxygen. The metal, if it be not volatile at the temperature required for its oxidizement, is exposed to the heat of the furnace in a flat dish of baked clay called a *roasting test*, and frequently stirred to present fresh surfaces to the air: but, if the metal be easily volatilized, as is the case with zinc, it is thrown by pieces, at separate intervals, into a deep crucible, so placed as to admit the air and allow of the additions being made. If mercury be the metal operated on, it is generally put into a flat-bottomed matrass with a very tall narrow neck, the mouth of which is left open, and which is placed in a sand-bath, and kept at a degree of heat nearly equal to the boiling point of the mercury, for several days; but it is perhaps better to use a retort with the bottom flattened, and the neck only slightly bent, that the globules of mercurial vapour may be condensed, and the metal

fall back into the vessel.* In this process the atmospheric air furnishes the oxygen, which readily combines with the volatilized mercury, while the form of the apparatus is intended to permit a renewal of it constantly to take place, without allowing the escape of the mercurial vapour.

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

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

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

* *Higgins's Minutes. Aikin's Dictionary*, ii. 75.

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

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

COATINGS, CEMENTS, AND LUTES.

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

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

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

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

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

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

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

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

† Lavoisier.

5. Take four parts of common resin, one of yellow wax, and one part of fine brick-dust; melt the two former together, and when they are melted stir in the brick-dust. This lute adheres with great firmness, and forms also a good cement for stopping cracks in glass vessels.
6. Six parts of clay, one part of iron filings, and enough of linseed oil to form them into a paste, make a good cement for stopping cracks in iron vessels intended to be strongly heated.
7. The following cement is recommended for joining together glass or steel. "Take of mastich five or six bits as big as peas, and dissolve them in as much alcohol as will render them liquid. In another vessel dissolve as much isinglass (previously soaked in water) in brandy or rum as will make two fluid ounces of a strong glue; warm it, and incorporate with it by rubbing, two or three small bits of galbanum or ammoniacum, and the mastich solution. Preserve the mixture in a well-stopped bottle, and gently warm it before use."¹
- b. *Mucilaginous and gelatinous Lutes* are adapted only for operations which do not require a high temperature, and in which very acrid vapours are not extricated. They are easily applied, are sufficiently adhesive, and can be readily removed, by simply moistening them with water.
 1. Under this head may be mentioned the simple application of moistened bladder. To render it very adhesive, it should be soaked in tepid water, until it feels clammy to the touch; after which it contracts considerably as it dries, and adheres with a sufficient degree of force.
 2. Linseed meal kneaded up with water to a sufficient consistence, and applied pretty thick over the joinings of the vessels, or almond meal treated in the same manner, form very convenient lutes, which dry and become firm in a very short time.
 3. Flour paste spread upon slips of moistened paper forms a sufficiently good lute for many purposes.
 4. Smear slips of linen on both sides with white of egg, then apply these neatly to the joinings of the vessels, and when applied shake loosely over them some finely powdered quicklime. This lute dries very quickly, is extremely hard, very cohesive, impervious to water, and impenetrable by most kinds of vapours.
 5. Mix powdered plaster of Paris with white of egg, milk, glue, starch, or any mucilage, and apply it immediately.
 6. Mix together equal parts of clay and lime, with about one-third of flour and white of egg.

¹ Aikin's Dictionary of Chemistry.

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

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

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

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

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

¹ Aikin's Dictionary of Chemistry.

APPENDIX TO PART I.

No. I.

TABLE OF FREEZING MIXTURES.

The following Tables were drawn up by Mr. Walker from actual experiments. They show the degree of cold, or the reduction of temperature, which may be obtained by the different combinations mentioned in the first column.

TABLE I.

FRIGORIFIC MIXTURES—WITHOUT ICE.

Mixtures.	Thermometer sinks.	Degree of cold produced.
Parts.		
Muriate of ammonia 5 Nitrate of potash - 5 Water - - - 16	From + 50° to + 10°	40
Muriate of ammonia 5 Nitrate of potash - 5 Sulphate of soda - 8 Water - - - 16	From + 50° to + 4°	46
Nitrate of ammonia - 1 Water - - - 1	From + 50° to + 4°	46
Nitrate of ammonia 1 Carbonate of soda - 1 Water - - - 1	From + 50° to - 7°	57
Sulphate of soda - 3 Diluted nitric acid - 2	From + 50° to - 3°	53
Sulphate of soda - 6 Muriate of ammonia 4 Nitrate of potash - 2 Diluted nitric acid - 4	From + 50° to - 10°	60
Sulphate of soda - 6 Nitrate of ammonia 5 Diluted nitric acid - 4	From + 50° to - 14°	64
Phosphate of soda - 9 Diluted nitric acid - 4	From + 50° to - 12°	62
Phosphate of soda - 9 Nitrate of ammonia 6 Diluted nitric acid - 4	From + 50° to - 21°	71
Sulphate of soda - 8 Muriatic acid - - 5	From + 50° to - 0°	50
Sulphate of soda - 5 Diluted sulphuric acid 4	From + 50° to + 3°	47

N. B. If the materials are mixed at a warmer temperature than that expressed in the table, the effect will be proportionably greater; thus, if the most powerful of these mixtures be made when the air is + 85°, it will sink the thermometer to + 2°.

TABLE II.

FRIGORIFIC MIXTURES—WITH ICE.

Mixtures.	Thermometer sinks.	Degree of cold produced.
Parts.		
Snow, or pounded ice 2	From any temperature.	to -5°
Muriate of soda - 1		
Snow, or pounded ice 5		
Muriate of soda - 2		
Muriate of ammonia 1		to -12°
Snow, or pounded ice 24	From any temperature.	to -18°
Muriate of soda - 10		
Muriate of ammonia 5		
Nitrate of potash - 5		
Snow, or pounded ice 12	From any temperature.	to -25°
Muriate of soda - 5		
Nitrate of ammonia 5		
Snow - - - - 3		
Diluted sulphuric acid 2	From 32° to -23°	55
Snow - - - - 6	From $+32^{\circ}$ to -27°	59
Muriatic acid - - 5		
Snow - - - - 7	From $+32^{\circ}$ to -30°	62
Diluted nitric acid - 4		
Snow - - - - 4	From $+32^{\circ}$ to -40°	72
Muriate of lime - 5		
Snow - - - - 2	From $+32^{\circ}$ to -50°	82
Cryst. muriate of lime 3		
Snow - - - - 3	From $+32^{\circ}$ to -51°	83
Potash - - - - 4		

N. B. The reason for the omissions in the last column of this table, is, the thermometer sinking in the mixtures to the degree mentioned in the preceding column, and never lower, whatever may be the temperature of the materials at mixing.

TABLE III.

COMBINATIONS OF FRIGORIFIC MIXTURES.

Mixtures.	Thermometer sinks.	Degree of cold produced.
Parts.		
Phosphate of soda - 5 Nitrate of ammonia 3 Diluted nitric acid - 4	From 0° to - 34°	34
Phosphate of soda - 3 Nitrate of ammonia 2 Diluted mixed acids 4	From - 34° to - 50°	16
Snow - - - - 8 Diluted sulphuric acid 3 } Or Diluted nitric acid 3 }	From - 10° to - 56°	46
Snow - - - - 3 Diluted nitric acid - 2	From 0° to - 46°	46
Snow - - - - 1 Diluted sulphuric acid 1	From 20° to - 60°	40
Snow - - - - 3 Muriate of lime - 4	From + 20° to - 48°	68
Snow - - - - 3 Muriate of lime - 4	From + 10° to - 54°	64
Snow - - - - 2 Muriate of lime - 3	From - 15° to - 68°	53
Snow - - - - 1 Cryst. muriate of lime 2	From 0° to - 66°	66
Snow - - - - 1 Cryst. Muriate of lime 3	From - 40° to - 73°	33
Snow - - - - 1 Diluted sulphuric acid 10	From - 68° to - 91°	23

N. B. The materials in the first column are to be cooled, previously to mixing, to the temperature required, by mixtures taken from either of the preceding tables.

N° II.

TABLES OF SIMPLE AFFINITY.

The following Tables were drawn up by Bergman, and additions made to them by others at different times. The substance, the attractions of which are to be shown, is placed at the head of a column, and the substances to which it has an attraction placed beneath, in the order of the forces of attraction.

OXYGEN.	Chrome Bismuth Lead Copper Tellurium Platina Mercury Silver Gold	Arsenic Molybdena	Acids:
Carbon			Arsenic
Charcoal			Lactic
Manganese		POTASH, SODA, and	Benzoic
Zinc		AMMONIA.	Acetic
Iron		Acids:	Boracic
Tin		Sulphuric	Sulphurous
Antimony		Nitric	Nitrous
Hydrogen		Muriatic	Carbonic
Phosphorus		Phosphoric	Prussic
Sulphur		Fluoric	Sulphur
Arsenic		Oxalic	Phosphorus
Nitrogen		Tartaric	Water
Nickel		Arsenic	Fixed oils
Cobalt		Succinic	
Copper		Citric	STRONTITES.
Bismuth		Lactic	Acids:
Caloric ?		Benzoic	Sulphuric
Mercury		Sulphurous	Phosphoric
Silver		Acetic	Oxalic
Arsenous acid		Mucic	Tartaric
Nitric oxide		Boracic	Fluoric
Gold		Nitrous	Nitric
Platina		Carbonic	Muriatic
Carbonic oxide		Prussic	Succinic
Muriatic acid		Oil	Acetic
White oxide of man- ganese		Water	Arsenic
White oxide of lead		Sulphur	Boracic
			Carbonic
OXYGEN.*	SULPHUR. PHOSPHORUS.	BARYTES.	Water
Titanium	Potash	Acids:	LIME.
Manganese	Soda	Sulphuric	Acids:
Zinc	Iron	Oxalic	Oxalic
Iron	Copper	Succinic	Sulphuric
Tin	Tin	Fluoric	Tartaric
Uranium	Lead	Phosphoric	Succinic
Molybdena	Silver	Mucic	Phosphoric
Tungsten	Bismuth	Nitric	Mucic
Cobalt	Antimony	Muriatic	Nitric
Antimony	Mercury	Suberic	Muriatic
Nickel		Citric	Suberic
Arsenic		Tartaric	

* Vauquelin's Table of the affinity of the metals for oxygen, according to the difficulty with which their oxides are decomposed by heat.

TABLES OF SIMPLE AFFINITY—continued.

<i>Acids:</i> Oxalic Tartaric Camphoric Sulphuric Mucic Muriatic Nitric Phosphoric Arsenic Fluoric Succinic Citric Lactic Acetic Boracic Prussic Carbonic	<i>Acids:</i> Tartaric Phosphoric Citric Succinic Fluoric Arsenic Lactic Acetic Boracic Prussic Carbonic Fixed alkalis Ammonia	Glucine Yttria Alumina Zircon Metallic oxides	NITRIC ACID. MURIATIC ACID. § Barytes Potash Soda Strontites Lime Magnesia Ammonia Glucine Alumina Zircon Metallic Oxides
		SULPHUROUS ACID. SUCCINIC. †	
		Barytes Lime Potash Soda Strontites Magnesia Ammonia Glucine Alumina Zircon Metallic oxides	FLUORIC ACID. BORACIC ACID . ARSENIC ACID ¶ TUNGSTIC ACID.
OXIDE OF TIN.	OXIDE OF ANTIMONY.		Lime Barytes Strontites Magnesia Potash Soda Ammonia Glucine Alumina Zircon Silex
<i>Acids:</i> Gallic Muriatic Sulphuric Oxalic Tartaric Mucic Arsenic Phosphoric Nitric Succinic Fluoric Mucic Citric Lactic Acetic Boracic Prussic Ammonia	<i>Acids:</i> Gallic Muriatic Benzoic Oxalic Sulphuric Nitric Tartaric Mucic Phosphoric Citric Succinic Fluoric Arsenic Lactic Acetic Boracic Prussic Fixed Alkalies Ammonia	PHOSPHORIC ACID. CARBONIC. ‡ Barytes Strontites Lime Potash Soda Ammonia Magnesia Glucine Alumina Zircon Metallic oxides Silex	ACETIC ACID. LACTIC ACID. SUBERIC ACID. **
		PHOSPHOROUS ACID.	Barytes Potash Soda Strontites Lime Ammonia Magnesia †† Metallic Oxides Glucine Alumina Zircon
OXIDE OF ZINC.	SULPHURIC ACID. PRUSSIC.*	Lime Barytes Strontites Potash Soda Ammonia Glucine Alumina Zircon Metallic Oxides	
<i>Acids:</i> Gallic Oxalic Sulphuric Muriatic Mucic Nitric	Barytes Strontites Potash Soda Lime Magnesia Ammonia		

* With the omission of all after ammonia.

† Ammonia should come before magnesia; and strontites, glucine, and zircon be omitted.

‡ Magnesia should stand above ammonia, and alumina and silica be omitted.

§ Ammonia should stand above magnesia.

|| Silex should be omitted, and water and alcohol inserted.

¶ Except silex.

** With the omission of strontites, metallic oxides, glucine, and zircon.

†† Magnesia should stand above ammonia.

TABLES OF SIMPLE AFFINITY—continued.

OXALIC ACID. TARTARIC ACID. CITRIC ACID.*	BENZOIC ACID.	Soda Barytes Ammonia Alumina Magnesia	ALCOHOL. Water Ether Volatile oil Alkaline sulphurets
Lime Barytes Strontites Magnesia Potash Soda Ammonia Alumina Metallic oxides Water Alcohol	White oxide of arsenic Potash Soda Ammonia Barytes Lime Magnesia Alumina	FIXED OILS. Lime Barytes Potash Soda Magnesia Oxide of mercury Metallic oxides Alumina	SULPHURETED HYDROGEN. Barytes Potash Soda Lime Ammonia Magnesia Zircon
	CAMPHORIC ACID. Lime Potash		

N° III.

TABLES of the specific gravities of substances, which are articles of the *Materia Medica*, at a temperature of 60° of Fahrenheit.

METALS and INFLAMMABLES.	Muriatic - - -	1·929
Mercury - - - 13·568	Acetic - - -	1·080
Sulphuret of mercury 10·000	Vinegar - 1·0135 to 1·0251	
Lead - - - 11·352	Distilled vinegar 1·007 to 1·0095	
Silver - - - 10·510	Citric acid - - -	1·0345
Bismuth - - - 9·822	Benzoic - - -	0·667
Copper - - - 8·895	Ammonia (liquid) - - -	0·9054
Arsenic - - - 8·310	Potash - - -	1·7085
Sulphuret of arsenic (red) 3·225	Soda - - -	1·336
(yellow) 5·315	Lime - - -	2·3908
Iron - - - 7·788	Magnesia - - -	2·3298
Sulphuret of iron - 4·518	Barytes - - -	4·000
Tin - - - 7·299	Alumina - - -	2·000
Zinc - - - 6·861	Sulphate of potash -	2·298
Manganese - - - 6·850	— soda - - -	2·246
Antimony - - - 6·712	— magnesia - - -	1·6603
Sulphuret of antimony 4·368	Alum - - -	1·719
Sulphur - - - 1·990	Nitrate of potash -	1·933
Charcoals - 0·223 to 1·526	Muriate of soda -	2·120
Bitumens - 0·892 to 1·357	— ammonia - - -	1·453
	— lime - - -	1·76
	Muriate of barytes -	2·8257
	Phosphate of soda -	1·338
	Acetate of potash -	2·1—?
	Tartrate of potash -	1·5567

SALINE SUBSTANCES.

* Zircon after alumina.

Tartrate of potash & soda	1·757
Supertartrate of potash	1·953
Carbonate of potash	2·012
— soda	1·421
— ammonia	0·966
— lime	2·7—
— magnesia	0·2941
— barytes	4·331
Sub-borate of soda	1·720

METALLIC SALTS.

Mercury, corrosive muriate	
of	5·1398
— mild muriate	7·1758
— subsulphate	6·444
Copper, sulphate of	2·1943
— acetate	1·779
Iron, sulphate of	1·880
— carbonate	3·333
— acetate	1·368
Lead, carbonate of	7·2357
— superacetate	2·345
Zinc, sulphate of	1·912

VEGETABLE SUBSTANCES AND PRODUCTIONS.

Cinchona bark	0·7840
Logwood	0·9130
Madder root	0·7650
Mahogany	1·0630
Red saunders	1·1280
Sassafras	0·4820
Gum arabic	1·5153
Hepatic aloës	1·3586
Socotorine aloës	1·3796
Amber (yellow)	1·0780
Ammoniacum	1·2071
Assafœtida	1·3275
Benzoin	1·0924
Camphor	0·9887
Catechu	1·4573
Elemi	1·0682
Euphorbium	1·1244
Galbanum	1·2120
Galipot	1·0819
Gambôge	1·2216

Honey	1·1390
Myrrh	1·3600
Olibanum	1·1732
Opium	1·3365
Opoponax	1·6226
Resin (common)	1·0727
Sagapenum	1·2008
Scammony (Aleppo)	1·2354
— (Smyrna)	1·2743
Storax	1·1098
Sugar (refined)	1·6060
Tragacanth	1·8161
Turpentine	0·991
Wax (yellow)	0·9648
— (white)	0·9686

FATS AND OILS.

Fat of beef	0·9232
— mutton	0·9235
— pork	0·9368
Tallow	0·9419
Butter	0·9423
Spermaceti	0·9438
Oil of linseed	0·9403
— olives	0·9153
— almonds	0·9170
Naphtha	0·8475
Oil of cinnamon	1·044
— cloves	1·036
— lavender	1·894
— mint	0·8982
— rosemary	0·9057
— chamomile	0·8943
— savine	0·9294
— carraway	0·9049
— anniseed	0·9867
— juniper	0·8577
— turpentine	0·8697
— amber	0·8867
Sulphuric ether	0·632
Nitric ether	0·9088
Alcohol	0·794
Proof spirit	0·916
Water (distilled)	1·000

N^o IV.RULES for reducing the volume of Gases to a mean height of the Barometer, and mean Temperature.¹

1. From the space occupied by any quantity of gas under an observed degree of pressure, to infer what its volume would be under the mean height of the barometer, taking this at 30 inches.

This is done by the rule of proportion; for, as the mean height is to the observed height, so is the observed volume to the volume required. For example, if we wish to know what space would be filled, under a pressure of 30 inches of mercury, by a quantity of gas, which fills 100 inches, when the barometer is at 29 inches.

$$30 : 29 :: 100 : 96.66.$$

The 100 inches would, therefore, be reduced to 96.66.

2. To estimate what would be the volume of a portion of gas, if brought to the temperature of 60° Fahrenheit.

Divide the whole quantity of gas by 480; the quotient will show the amount of its expansion or contraction by each degree of Fahrenheit's thermometer. Multiply this by the number of degrees which the gas exceeds, or falls below 60°. If the temperature of the gas be above 60°, subtract, or if below 60° add the product to the absolute quantity of gas; and the remainder in the first case, or sum in the second, will be the answer. Thus, to find what space 100 cubic inches of gas at 50° would occupy if raised to 60°, divide 100 by 480; the quotient 0.208 multiplied by 10 gives 2.08, which added to 100 gives 102.08, the answer required. If the temperature had been 70°, and we had wished to know the volume, which the gas would have occupied at 60°, the same number 2.08 must have been subtracted from 100, and 97.92 would have been the answer.

3. In some cases it is necessary to make a double correction, or to bring the gas to a mean both of the barometer and thermometer.

We must then first correct the temperature, and afterwards the pressure. Thus to know what space 100 inches of gas at 70° Fah., 29 inches barometer, would fill at 60° Fah., and 30 inches barometer, we first reduce to 100 inches, by the second process, to 97.92. Then, by the first

$$30 : 29 :: 97.92 :: 94.63.$$

Or 100 inches thus corrected, would be only 94.63.

4. To ascertain what would be the absolute weight of a given column of gas at a mean temperature, from the known weight of an equal volume at any other temperature. First find by the second process what would be its bulk at a mean temperature; and then say, as the corrected bulk is to the actual weight, so is the observed bulk to the number required. Thus if we have 100 cubic inches of gas weighing 50 grains at 50° Fah., if the temperature were raised to 60°, they would expand to 102.08. And

$$102.08 : 50 :: 100 : 49.$$

Therefore 100 inches of the same gas at 60° would weigh 49 grains.

5. To learn the absolute weight of a given volume of gas under a mean pressure, from its known weight under an observed pressure, say, as the observed pressure is to the mean pressure, so is the observed weight to the corrected weight. For example, having 100 inches of gas which weigh 50 grains under a pressure of 29 inches, to know what 100 inches of the same gas would weigh, the barometer being 30 inches,

$$29 : 30 :: 50 : 51.72.$$

Then 100 inches of the same gas, under 30 inches pressure, would weigh 51.72 grains.

6. In some cases it is necessary to combine the two last calculations. Thus, if 100 inches of gas at 50° Fah., and under 29 inches pressure, weigh 50 grains, to find what would be the weight of 100 inches at 60° Fah., and under 30 inches of the barometer, first correct the temperature, which reduces the weight to 49 grains. Then,

$$29 : 30 :: 49 : 50.7.$$

100 inches, therefore, would weigh 50.7 grains.

¹ Vide Henry's *Elements of Experimental Chemistry*, vol. ii. p. 497.

N° V.

TABLES of the correspondence between measures of weight and capacity; according to the estimations given by Sir George Shuckburgh Evelyn, in vol. 88. of the *Phil. Trans.* corrected by Mr. Fletcher, in the 4th Vol. of the *Philosophical Journal*¹.

TABLE I.

For converting Cubic Inches of Water (at 60 Therm. and 29.5 Bar.) into their equivalents in Troy weight.

Cubic Inch of Water	Troy grs.	oz.	drachm	grs.
1 weighs	252.506	= 0	: 4	: 12.506
2	505.012	= 1	: 0	: 25.012
3	757.518	= 1	: 4	: 37.518
4	1010.024	= 2	: 0	: 50.024
5	1262.530	= 2	: 5	: 2.530
6	1515.036	= 3	: 1	: 15.036
7	1767.542	= 3	: 5	: 27.542
8	2020.048	= 4	: 1	: 40.048
9	2272.554	= 4	: 5	: 52.554
1728 (1 cub. foot)	909	: 0	: 10.368	

TABLE II.

For converting Troy Grains, Drachms, Ounces, and Pounds of Water into their equivalent Cubic Inches.

Grains.	Cubic Inch.	Drachm.	Cubic Inch.
1 =	.00396	1 =	.237618
2 =	.00792	2 =	.475236
3 =	.01188	3 =	.712854
4 =	.01584	4 =	.950472
5 =	.01980	5 =	1.188090
6 =	.02376	6 =	1.425708
7 =	.02772	7 =	1.663326
8 =	.03168		
9 =	.03564		
Ounce.	Cubic Inch.	Pound.	Cubic Inch.
1 =	1.900945	1 =	22.81134
2 =	3.801890	2 =	45.62268
3 =	5.702835	3 =	68.43402
4 =	7.603780	4 =	91.24536
5 =	9.504725	5 =	114.05670
6 =	11.405670	6 =	136.86804
7 =	13.306615	7 =	159.67938
8 =	15.207560	8 =	182.49072
9 =	17.108505	9 =	205.30206
10 =	19.009450		
11 =	20.910395		

¹ Not having the fourth Volume of the *Philosophical Journal* by us, we have copied these Tables from the Appendix of Aikin's Dictionary.

TABLE III.

For converting Wine Pints of Water into their equivalent Troy and Avoirdupois Pounds.

Wine Pints.	lbs. Troy.	lbs.	oz.	dr.	grs.	lbs. Averd.
1 =	1·26581783 =	1 :	3 :	1 :	31·1 =	1·04158725
2 =	2·53163566 =	2 :	6 :	3 :	2·2 =	2·08317450
3 =	3·79745349 =	3 :	9 :	4 :	33·3 =	3·12476175
4 =	5·06327132 =	5 :	0 :	6 :	4·4 =	4·16634900
5 =	6·32908915 =	6 :	3 :	7 :	35·5 =	5·20793625
6 =	7·59490698 =	7 :	7 :	1 :	6·6 =	6·24952350
7 =	8·86072481 =	8 :	10 :	2 :	37·7 =	7·29111075
8 =	10·12654264 =	10 :	1 :	4 :	8·8 =	8·33269800
9 =	11·39236047 =	11 :	4 :	5 :	39·9 =	9·37428525

TABLE IV.

For converting Troy Pounds of Water into their equivalent Wine Pints.

Troy Pound.	Wine Pints.	Troy Pounds.	Wine Pints.
1 =	0·7900031	6 =	4·7400186
2 =	1·5800062	7 =	5·5300217
3 =	2·3700093	8 =	6·3200248
4 =	3·1600124	9 =	7·1100279
5 =	3·9500155		

TABLE V.

For converting Avoirdupois Pounds into their equivalent Troy Pounds.

lbs. Averd.	lbs. Troy.	lbs. Averd.	lbs. Troy.
1 =	1·215277	6 =	7·291666
2 =	2·430555	7 =	8·506944
3 =	3·645833	8 =	9·722222
4 =	4·861111	9 =	10·937500
5 =	6·076388		

TABLE VI.

For converting Troy Pounds into their equivalent Avoirdupois Pounds.

lbs. Troy.	lbs. Averd.	lbs. Troy.	lbs. Averd.
1 =	0·82285714	6 =	4·93714285
2 =	1·64571428	7 =	5·76000000
3 =	2·46857142	8 =	6·58285714
4 =	3·29142857	9 =	7·40571428
5 =	4·11428571		

TABLE VII.

For converting Ounces, Drachms, and Grains Troy into Decimals of the Troy Pound.

Grains.	lbs. Troy.	Drachms.	lbs. Troy.	Oz.	lbs. Troy.
1	= .000173611	1	= .0104166	1	= .0833
2	= .000347222	2	= .0208333	2	= .1666
3	= .000520833	3	= .0312500	3	= .2500
4	= .000694444	4	= .0416666	4	= .3333
5	= .000868055	5	= .0520833	5	= .4166
6	= .001041666	6	= .0625000	6	= .5000
7	= .001215277	7	= .0729166	7	= .5833
8	= .001388888			8	= .6666
9	= .001562500			9	= .7500
				10	= .8333
				11	= .9166

TABLE VIII.

For converting Decimals of the Troy Pound into Troy Ounces, Drachms, and Grains.

lbs.	oz.	dr.	grs.	lbs.	oz.	dr.	grs.	lbs.	grs.
.1	= 1	: 1	: 36	.01	= 0	: 0	: 57.6	.001	= 5.76
.2	= 2	: 3	: 12	.02	= 0	: 1	: 55.2	.002	= 11.32
.3	= 3	: 4	: 48	.03	= 0	: 2	: 52.8	.003	= 17.28
.4	= 4	: 6	: 24	.04	= 0	: 3	: 50.4	.004	= 23.04
.5	= 6	: 0	: 0	.05	= 0	: 4	: 48.0	.005	= 28.80
.6	= 7	: 1	: 36	.06	= 0	: 5	: 45.6	.006	= 34.56
.7	= 8	: 3	: 12	.07	= 0	: 6	: 43.2	.007	= 40.32
.8	= 9	: 4	: 48	.08	= 0	: 7	: 40.8	.008	= 46.08
.9	= 10	: 6	: 24	.09	= 0	: 8	: 38.4	.009	= 51.08

N° VI.

TABLE shewing the correspondence between the new French and the English weights and measures.

I. MEASURES OF LENGTH.

The metre being at 32°, and the foot at 62°.

		English Inches.							
Millimetre	=	·03937							
Centimetre	=	·39371							
Decimetre	=	3·93710							
Metre	=	39·37100							
Decametre	=	393·71000	=	0	0	10	2	9·7	
Hecatometre	=	3937·10000	=	0	0	109	1	1	
Kilometre	=	39371·00000	=	0	4	213	1	10·2	
Myriametre	=	393710·00000	=	6	1	156	0	6	

II. MEASURES OF CAPACITY.

		Cubic Inches.							
Millilitre	=	·06103							
Centilitre	=	·61028							
Decilitre	=	6·10280							
Litre	=	61·02800	=	0	0	0		2·1138	
Decalitre	=	610·28000	=	0	0	2		5·1352	
Hecatolitre	=	6102·80000	=	0	0	26·419			
Kilolitre	=	61028·00000	=	1	0	12·19			
Myriolitre	=	610280·00000	=	10	1	58·9			

III. MEASURES OF WEIGHT.

		English Grains.							
Milligramme	=	·0154							
Centigramme	=	·1544							
Decigramme	=	1·5444							
Gramme	=	15·4440							
Decagramme	=	154·4402							
Hecatogramme	=	1544·4023	=	0	3	8·5			
Kilogramme	=	15444·0234	=	2	3	5			
Myriogramme	=	154440·2344	=	22	1	2			