THE

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 thence, 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 can neither be theoretically understood, nor 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 an account of the 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 explanations of the operations of Pharmacy, with a description of the apparatus.

TABLE OF ARRANGEMENT.

SECTION I.

OF THE MORE GENERAL AGENTS INFLUENCING PHARMACEUTICAL COMBINATIONS.

I. ATTRACTION.

a. *Attraction of Aggregation.*
b. *Chemical Attraction, or Affinity.*

II. REPULSION.

Powers by which it is produced.

1. CALORIC.
2. LIGHT.
3. ELECTRICITY and GALVANISM.

SECTION II.

OF THE CONSTITUTIONS AND COMBINATIONS OF SUBSTANCES.

1. OF SOLIDS.
2. OF FLUIDS.
3. OF AËRIFORM SUBSTANCES or GASES.

SECTION III.

OF PHARMACEUTICAL OPERATIONS AND THE DESCRIPTION OF THE APPARATUS.

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 power 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 power, 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 power is exerted on masses of matter, at sensible distances, in the direct ratio of the quantity of the matter, and

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the inverse ratio 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 causes bodies on this globe to fall in a line perpendicular to its surface, 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 upon the surface of our globe. It is this species which we are here to examine.

CONTIGUOUS ATTRACTION, operating on particles of the same kind, forms an aggregate or mass; and 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 force 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 one another, 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 one another, until the fluid passes into the gaseous form, or becomes steam. This power is also weakened by chemical affinity; for, 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 its 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 greater relative distances, 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 thence, 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. Thus, a portion of air which can be contained in a vessel of 1 cubical inch of capacity, will fill a vessel of 100 cubical inches of capacity, if the pressure which confines it within the smaller vessel be removed.

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 bodies in passing from the fluid to the solid state, when nothing opposes the union of their particles according to the laws of aggregation.

The process of *crystallization* requires that the particles of the substance to be crystallized become moveable; and, consequently, in order to obtain any body in a crystalline state, it must first be rendered fluid, either by solution in a liquid, or by fusion.

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 the salt, and set the solution aside to cool. As the caloric is dissipated, the saline particles gradually approach one another, and uniting, form solids of that regular shape which characterizes the crystals of this peculiar salt. But, when the salt is one which is almost equally soluble in hot and in cold water, as muriate of soda, for instance, its

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crystallization can be effected only by evaporating a part of the fluid; and the more slowly the evaporation proceeds, 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 greater reduction of temperature in the one case, and a further evaporation in the other, 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 one another, these, when the cooling is gradual, assume, in aggregating again, 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 Haüy. 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, 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, which includes 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 Haüy 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 third 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, but electively, between the particles of all bodies. 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 when applied to animal matter, 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

[1] For many of the following observations on affinity, I am indebted to the remarks of my late respected friend, Dr. Murray: see his *System of Chemistry*, vol. i.

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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 the components than these have for each other: and by such means, which constitute *chemical analysis*, the principles of a compound may be ascertained.

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, *muriatic gas* and *ammoniacal gas* form a fluid: that of two fluids, again, may form a solid, as is demonstrated by dropping into a saturated solution of *muriate of lime*, some concentrated *sulphuric acid*; 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 thence, 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 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; and there is a diminution of volume, owing, probably, to the compound atom being of a form admitting a more compact aggregation than the component atoms in their separate state; but 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 water, which is solidified by being mixed with quicklime, parts with a large portion of caloric. 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.[1]

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 a 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 di-

[1] See Appendix to Part I. No. I.

minish 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 of considerable weight have been advanced to the opinions of Berthollet on this subject, by Pfaff, Sir H. Davy, and others: but it is unnecessary to enter into an examination of them at the present moment; and we may only observe, that the theory of Berthollet, however plausible, is not unobjectionable: so that it is, perhaps, better for the student to regard affinity as truly *elective*, and that the constituents of all compound bodies are constant.

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 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 one another.[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 thence, *agitation* is frequently necessary for aiding the operation of affinity.

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

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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 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 aëriform 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.

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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 are 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. Such compounds, therefore, when they are intended to act *medicinally*, should be exhibited as soon as possible after they are made.

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 that of 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. The remarks of Berthollet may have tended to lessen their value in the opinions of some; but 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 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.[2]

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 those of another.

But the changes produced by the predominance of certain affinities over others, 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 have, 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

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[1] See Appendix to Part I. No. II.

[2] 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 / 62 ▽ / Sulphuric acid 54 } { Muriatic acid / 20 = 82 / Lime } Muriate of lime.

Sulphate of lime.

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 precisely 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, Berthollet's Researches into the Laws of Chemical

[1] *Researches*, p. 3. quoted by Murray, *System of Chemistry*, i. 120.
Henry's Elements of Experimental Chemistry, 7th ed. vol. i. p. 57.

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Affinity, Richter's Foundation of Stochiometry, and Sir Humphrey Davy's Elements of Chemical Philosophy.

II. REPULSION.

REPULSION is that force which separates the particles of bodies from one another, 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*. Philosophers are not completely agreed whether it is a property only of bodies, such as a vibration of their particles,[1] or a peculiar substance; but the latter opinion is the one more generally adopted.

Under this opinion caloric is regarded as a very subtile, 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, while their density is diminished. 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, and of polarization, like those of light. 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 160°. 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.

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[1] The idea of caloric being motion or vibration orginated with Lord Bacon.
[2] *Philosophical Trans.* 1807. [3] Ib. 1799, p. 179.

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

When a combustible is heated to a certain degree, it becomes still hotter of itself, and 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 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 following facts: 1. combustion does not go on unless oxygen be present; and it is more brilliant in oxygen gas than in common air: 2. the products of combustion are always heavier than the body consumed; and, 3. 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." [1]

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

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

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, when all the circumstances are equal; the estimate being formed from the quantity of ice melted during the burning of one pound of each of the substances.[1]

Substances burnt, 1 lb.	Oxygen consumed in lbs.	Ice melted in lbs.			
		Lavoisier.	Crawford	Dalton.	Rumford.
Hydrogen	6	295	480	320	
Carburetted hydrogen	4	—	—	85	
Olefiant gas	3·5	—	—	88	
Carbonic oxide	0·58	—	—	25	
Olive oil	3·5	148	89	104	93·073
Rape oil	—	—	—	—	124·097
Wax	3·5	133	97	104	126·242
Tallow	3·5	—	—	104	111·582
Oil of turpentine	—	—	—	60	
Alcohol	—	—	—	58	67·470
Sulphuric æther	3·	—	—	62	107·027
Naphtha	—	—	—	—	97·834
Phosphorus	1·5	100	—	60	
Charcoal	2·8	96·5	69	40	
Sulphur	1·36	—	—	20	
Camphor	—	—	—	70	
Caoutchouc	—	—	—	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 become 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 oxidizement

[1] *Thomson's Chemistry*, 4th edit. i. 610.

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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 undetermined.

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.

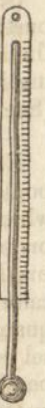
Such are the sources from which caloric is obtained. Combustion is the most important of these; and the knowledge of the laws by which it is regulated, and of the modes of conducting it, is of the first consequence in the practice of pharmacy. (See *Furnaces.*)

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, the temperature of the water 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 become as cold as they are, or until its temperature be lowered to an equilibrium with theirs. The caloric lost by 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 changes of the portion of medium immediately in contact with the hot body; produced by the change of density occasioned by the caloric they receive from the hot body, enabling them 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 thence 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 than the human body 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, the conducting power of the body which is touched, 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. 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 relative 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 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.[1] As the instrument may be occasionally plunged into corrosive fluids, the stem and bulb should project beyond the scale; or the scale may turn up with a hinge.

[1] Thermometers of great accuracy may be purchased. Persons 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*.

For ordinary purposes, mercury is the fluid 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 Fahrenheit[1]: 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 it and the boiling point is equal to 180 degrees. The scale may be extended above this point and, also, below the commencement of the scale, the descending degrees being marked inversely with the same numbers as the ascending.

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 $\frac{4}{9}$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 degrees. Each degree is, therefore, $\frac{1}{4}$ths more than one of Fahrenheit's; and to reduce the scale of Reaumur to that of Fahrenheit, the given number of degrees of the former must be multiplied by 9, and divided by 4, adding 32 to the quotient.[2]

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

[1] Fahrenheit was an artist of Amsterdam. [2] See Note on the next page.

degree of fallacy attends the observations made with them, 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 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 the general law of its operation.

When caloric flows into a body, it separates its integrant particles from one another, 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 reverse 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.

TABLE shewing 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·	18·
69	55·2	156·2	37	29·6	98·6						

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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 the bulk of pure clay diminishes, when heated, in the ratio of the intensity of the heat to which it is exposed.[1] 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

TABLE exhibiting the degrees of the centigrade 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	5·5	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			

[1] For measuring higher temperatures than the thermometer can be subjected to, instruments named *pyrometers* have been employed; the best of which is that in-

which, consequently, most readily assume the gaseous form. The degree of their expansion, also, increases, with the augmentation of the 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 Mr. Dalton, shews the expansion of the more common liquids, from 32° to 212° of Fahrenheit, the volume at 32° being denoted by 1.

Mercury.	Water.	Water saturated with salt.	Sulphuric acid, sp. gr. 1·85.	Muriatic acid, sp. gr. 1·137.	Oil of Turpentine.	Ether.	Fixed oils.	Alcohol.	Nitric acid, sp. gr. 1·40.
.0200 =	.0466 = $\frac{1}{21.5}$	.0500 = $\frac{1}{20}$	.0600 = $\frac{1}{17}$	.0600 = $\frac{1}{17}$	.0700 = $\frac{1}{14\frac{1}{2}}$	.0700 = $\frac{1}{14}$	.0800 = $\frac{1}{12.5}$	.0110 = $\frac{1}{9}$	.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°, 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

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vented by Mr. Wedgewood. 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 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 21·877° 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.

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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 $\frac{1}{480}$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 one another 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 sufficient degree of heat; and all liquids, with the exception of alcohol and ether, 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.[1] 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 into water is an example of the first; the melting of glass, of wax, and other unctuous matters, are instances 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* under the ordinary pressure of the atmosphere: — a piece of wood, for instance, cannot be melted by the application of any degree 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 consider-

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

Lead -	612°	Copper - - -	4587°, *Fahr.* 28, *Wedg.*	Spermaceti	112°
Bismuth -	476	Silver - - -	4717 28	Phosphorus	100
Tin -	442	Iron - - - -	21637 157	Tallow -	92
Zinc -	703	Sulphur - - -	218	Oil of anise	50
Antimony	809	Bees-wax - -	142	Camphor -	303
Mercury -	39	Lard - - -	97	Ice - -	32

ably. 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 salts renders this point still lower, as may be seen by the following table.[1]

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·
——————— 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 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 rather have entered the ice, and as the caloric is no longer sensible to the thermometer, it is justly said to have become latent: thence 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 state of vapour, becoming invisible and elastic, and possessing the other mechanical properties of air.

[1] *Phil. Trans.* 1788, 27, quoted by Dr. Thompson.—Syst. Chemistry, 4th edit. i. 520.

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Evaporation, however, is also spontaneously produced, partly by the agency of caloric alone, partly by 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*, or conversion into vapour, 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*, as this degree of temperature is termed, 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 96°, of alcohol 173°, of pure water 212°, of water saturated with common salt 225°, of mercury 656°, and so on. In a vacuum all liquids boil at a temperature 124° 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 such a pressure 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 fluid after it arrives at its boiling point; and retains it in a latent form: for the vapour is not sensibly hotter than the boiling liquid: thus, steam, the temperature of which is indicated by the thermometer to

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

be 212°, is water combined with 940° of caloric, which remain latent as long as the temperature of the steam is maintained at 212°, but is again given out when a lower temperature changes that vapour to the state of a liquid.

Gases resemble vapours in their constitution, but differ from them 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. Are they compounds of solid or of liquid substances and caloric? Ammoniacal gas condenses into a fluid at 45°; and many of the other gases have been condensed into fluids by Mr. Faraday; but the question may be regarded as still *sub judice*.

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 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 it produces decomposition; but in some it favours 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 in a different vessel, is obtained as a distinct substance. Almost all compounds into which oxygen has entered without having occasioned combustion, as nitric 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 their composition, are those which

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have been formed by combustion; such as water, phosphoric acid, and carbonic acid.[1] 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 subtile particles, which are constantly emanating in straight lines from luminous bodies. Some philosophers, however, following Hooke and Huygens, believe, that light is merely the state of undulation of a highly rare, elastic substance, which it is supposed fills the whole of the universe: but this hypothesis is inconsistent with the fact, that a ray of light which has suffered ordinary refraction in passing through a crystal in one direction, should suffer ordinary refraction in passing through it in another direction; whilst this fact perfectly accords with the idea that light consists of particles endowed with rectilineal motion. The size of the particles of light 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 the particles of caloric.

A ray of light falling obliquely upon a polished surface is *reflected* from it at an angle equal to the angle of its incidence. But when a ray of light falls at an angle of 35° 25′ on a polished plate of glass; and, in being reflected from it, falls upon another plate of glass, so placed that its angle of incidence is also 35° 25′; the second plate may be turned round its axis without varying the angle which it makes with the ray that falls upon it. If the two planes of reflection be parallel to each other, the ray of light is reflected in the same manner from both plates of glass; but if the second plate be turned round a quadrant of a circle, so as to make the plane of reflection perpendicular, the whole ray will pass through it, and none of it be reflected; yet, if this plate be turned round another quadrant of a circle, so as to make the reflecting planes again parallel, the ray will be now reflected by it as at first. The light can penetrate through the glass only when the reflecting planes are perpendicular, but is reflected when they are parallel. This property of light has been termed by Malus, by whom it was first discovered, its *polarization.*

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

Universitäts- und Landesbibliothek Düsseldorf urn:nbn:de:hbz:061:2-135391-p0047-4

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 is refracted 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; and when a liquid is converted into vapour, its refractive power diminishes at a greater ratio than its density diminishes.[1]

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 follow 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

[1] See the experiments of Arago and Petit, in the *Ann. de Chem. et Phys.* tom. i. 1.

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three different 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. 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 paler 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 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: and the colour and the properties of vegetable powders kept in clear glass bottles are, also, affected by them. 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. Chaptal[1] 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 Ritter[2] 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 subtile fluid, which is a powerful chemical agent, capable of producing immediate decompositions and new combinations. Galvanism appears to be essentially the same as electricity, differing,

[1] *Journal de Physique*, xxxiii. 297. [2] *Nicholson's Journ.* viii. 216.

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: thence 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, plumbago, charcoal, and most liquids 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 one another, 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 one another; but if one of them be electrified positively and the other negatively, they attract one another. 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.

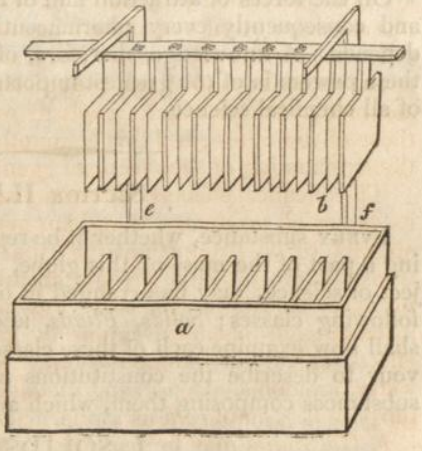
The chemical effects of electricity seem to depend, chiefly, on its power of producing a sudden high temperature; and this appears to be proportioned to the resistance opposed to its transmission. It often favours chemical combinations; as for instance, that of oxygen with the metals, and promotes the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

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 ex-

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tent, Plumbago, Water, the mineral acids, and saline solutions, are perfect conductors; 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 muriatic 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 trough, or one of earthenware, 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 every double plate looking towards one 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 their surfaces, but, for producing chemical decomposition, on the number of plates. The more improved apparatus now used, is a trough of earthenware, *a*, 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, *b*, 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. The whole of these plates are attached to a wooden bar, so that they can be removed at the pleasure of the operator, and supported on hooks fixed in the cross bars of the props *e*, *f*, attached to the side of the trough.



[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.

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.

By placing any body, one, for instance, composed of oxygen and an inflammable substance, in connexion with the metallic wires proceeding from each end of a galvanic battery, the oxygen is attracted by the wire which is in the positive state, and repelled by that which is in the negative; while, at the same time, the inflammable is attracted by the negative wire, and repelled by the positive. Hence the components are separated, and obtained in a distinct 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 to the eye; a sensation of acidity on the tongue, and of pain on the muscles; 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. It has not yet been employed as a pharmaceutical agent, except for detecting the presence of oxymuriate, bichloride of mercury, when exhibited as a poison. (See PART 3.)

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, which are objects of pharmacy.

I. SOLIDS.

SOLID bodies are masses of homogeneous particles combined

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

and held together by the attraction of aggregation or cohesion. The arrangement of the particles with regard to one another is, often, such as to produce regular figures, in which case the solids are said to be crystallized. Cohesion and crystallization have been already considered.

CONSTITUTION OF SOLIDS.

Arrangement of the principal Solids according to their Composition.

I. SIMPLE, *or* UNDECOMPOUNDED.

Sulphur. *Carbon.* *Metals.*
Phosphorus. *Boron.*

II. COMPOUNDS.

Sulphurets of Metals.
———— *fixed Alkalies.*
———— *Earths.*
Oxide of Phosphorus.
Phosphurets of Carbon.
———— *Metals.*
———— *Earths.*
Charcoal.
Metallic Oxides.
———— *with Alkalies.*
Carburets of Iron.
Alloys.
Earths.
—— *with Earths.*
———— *metallic Oxides.*
———— *fixed Alkalies.*
Solid Acids.
Salts and Hydrosulphurets.
Bitumens, solid oils.
Soaps.
Most vegetable Substances.
Many animal Substances.

SIMPLE SOLIDS.

a. SULPHUR. Although the experiments of Sir H. Davy[1] 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.

[1] *Elements of Chem. Phil.* p. 283.

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b PHOSPHORUS is semitransparent, of a yellowish red or amber colour, and a waxy consistence; but, when perfectly pure, it is colourless and transparent. Its specific gravity is 1·770. It is nearly insoluble in water, and is so soft that it may be cut with a knife. It is brittle at a temperature under 32°. Above that point it softens, and under 90° is very ductile. It melts at 90°; in close vessels is volatilized at 219°; and boils at 554°. When heated in the air to 148° it inflames, and emits a white smoke, which is luminous in the dark, has an alliaceous odour, and condenses to an acid. It is obtained from urine, bones, and other animal matters. From Sir H. Davy's experiments, there appear to be circumstances which favour the idea that it is a compound; but it is, still, generally regarded as an undecompounded body.[1]

c. 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.

d. 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 metal only, Mercury, is in a fluid state at the ordinary heat of the air. Many Metals possess considerable tenacity, and are consequently malleable and ductile; but some are extremely brittle. They 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.

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[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*, vol. ii. p. 7.

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The following metals or their compounds are used as pharmaceutical agents.

I. MALLEABLE.

1. Silver. (*See Part* ii.)
2. Mercury. (*Ibid.*)
3. Copper. (*Ibid.*)
4. Iron. (*Ibid.*)
5. Tin. (*Part* ii.)
6. Lead. (*Ibid.*)
7. Zinc. (*Ibid.*)
8. Potassium, obtained by decomposing potass, is white, has the metallic lustre of silver, is soft and malleable at 50°, but at 32° is hard and brittle. Its sp. gr. at 60° is 0·86507. It becomes fluid at 136½°, and at a red heat is converted into vapour. It combines rapidly with oxygen and forms *potass*.
9. Sodium, obtained by decomposing soda, is white, has the lustre of lead, is very soft and malleable at 60°, and retains these properties at 32°. It sp. gr. is 0·97223. It melts at 194°; and requires a higher temperature to be volatilized than potassium. It combines rapidly with oxygen, and forms *soda*.
10. Calcium, obtained from lime, is yet imperfectly known. Combined with oxygen it forms *lime*.
11. Barium, obtained by decomposed barytes, is a metal of the colour of silver, melts at a low heat, but is not volatilized in a heat capable of melting plate glass. Combines rapidly with oxygen, and forms *barytes*.
12. Magnesium is a white solid metal, having the colour of silver. It is heavier than water, which it decomposes, although less rapidly than potassium and the other alkaline metals, and is converted into *magnesia*.

II. BRITTLE AND EASILY FUSED.

1. Bismuth. (*Part* ii.)
2. Antimony. (*Ibid.*)
3. Arsenic. (*Ibid.*)

III. BRITTLE AND DIFFICULTLY FUSED.

1. Manganese. (*Part* ii.)

e. BORON is obtained from the decomposition of boracic acid, in the form of powder, of a deep olive colour, insipid, inodorous, and insoluble in water. 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 that acid by decomposing sulphuric and nitric acids when it is treated with them. It combines with the alkalies and with sulphur.

COMPOUNDS.

a. COMPOUNDS OF SULPHUR.

1. *Sulphurets of metals* are compounds of sulphur and metals, inodorous, insipid, often possessed of metallic brilliancy, and brittle. They 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.	Weight of an atom of the sulphur .
Mercury	1. Black - -	8·16	8	27
	2. Red - -		16	29
Iron - -	1. Yellow -	4·518	57·1	5·5
	2. Yellow -	4·830	114·2	7·5
Antimony	Leaden gray	4·368	37·25	

2. *Sulphurets of fixed alkalies* are opaque, solid bodies, of a brownish red or liver colour; decomposable by caloric, water, and acids; and, by exposure to the air, convertible into hydrogureted sulphurets.
   Officinal. Sulphuret of potash. (*Part* ii.)
3. *Sulphurets of earths* resemble the alkaline sulphurets in their properties.
4. *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. COMPOUNDS OF PHOSPHORUS.

1. *Oxide of Phosphorus*, produced by heating phosphorus in highly rarefied air, assumes the form of red flakes, which take fire when slightly heated, and burn with a very vivid flame. By 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.
3. *Phosphurets of metals* are generally brittle, and have a metallic lustre. Vide *Annales de Chemie*, 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.)

Universitäts- und Landesbibliothek Düsseldorf urn:nbn:de:hbz:061:2-135391-p0056-4

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; some times 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, caloric, hydrogen, carbon, oils, &c.[1]

Table of officinal metallic oxides, shewing 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.
Potassium	White	20	Copper	Red	12·5
Sodium - -	White	33·3		Black	25
Calcium -	White	38·39	Zinc - - -	White	24·24
Barium - -	White	11·42	Bismuth -	White	11·28
Magnesium	White	66·6	Antimony	Yellow	18·60
Silver - -	Olive	7·272			
Mercury	Black	4	Arsenic	White	34·93
	Red	8		White	52·4
Iron - -	Black	28·75			
	Red	48·12	Manga-	Green	28·75
	Yellow	7·692	nese	Black	57·5
Lead - -	Red	11·53			
	Brown	15·384			

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.[2] It is a conductor of

[1] 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 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.

[2] Pencils made of plumbago were used so early as 1565, being mentioned by Conrade Gesner, in his book on fossils, printed at Zurich in that year. "Stylus inferius depictus, ad scribendum factus est, plumbi cujusdam (factitii puto, quod ali-

electricity; and 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 lusture, and differing in colour from the metals that form their basis.
6. *Metallic oxides with alkalies.*
7. *Earths.* (*Part* iii.)
   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, but, more usually, it is somewhat opaque, or resembles enamel; is inodorous, very acid, reddens vegetable 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 hissing noise; but, nevertheless, much heat is not evolved. It is decomposed at a high temperature by hydrogen, charcoal, and several of the metals. The composition of phosphoric acid is 100 of phosphorus, and 200 of oxygen.
   Phosphate of lime is found very abundantly in the native state. It 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, and insoluble in water, but is decomposed by several of the acids. Exposed to a heat of 378° Wedgwood, 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.*--Acid 100, lime 40·27.[1]
   Subspecies 3. *Quadri-phosphate of lime.*
   Subspecies. 4. *Sub-phosphate of lime.*--Acid 100, lime 118·5.[2]
   Phosphate of soda. (*Part* iii.)

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quis *stimmi anglicum* vocare audio) genere, in mucronem derasi, in manubrium ligneum inserti."—*De rerum fossilium figuris*, p. 104, quoted by Beckman, History of Inventions, vol. iv. p. 350.

[1] Rose.

[2] *Thomson's Syst. of Chem.* 5th edit. vol. ii. p. 460; quoted from Vauquelin, *Journ. de Min.* No. 27. p. 2.

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2. *Boracic acid* is obtained in the form of white, thin, irregularly 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 swells up when exposed to the fire, and 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 boron, and two of oxygen: but, according to Gay Lussac, and Thenard, the proportions are, two of boron, and one of oxygen.
Sub-borate of soda. (*Part* iii.)
3. *Benzoic acid.* (*Ibid.*)
4. *Succinic acid.* (*Ibid.*)
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. The solution of one part of the acid in 3600 parts, by weight, of water, is perceptibly acid to the taste. Exposed to heat in open vessels, it is decomposed. According to Berzelius, 100 parts contain fifty-two of real acid, and forty-eight of water; and the dry acid is a compound of hydrogen, 0.244.; carbon, 33·222.; and oxygen, 66.534.[3] Oxalic acid has been swallowed by mistake for Epsom salts, and has produced fatal effects in many instances. I was the first who ascertained, by experiments on dogs and rabbits, that it acts on the stomach like other corrosive poisons; and that a mixture of chalk and water is the best antidote.[2]
6. *Tartaric acid.* (*Part* iii.)
Tartrate of Potash. (*Ibid.*)
Variety. *Supertartrate of potash.* (*Part* ii.)
Tartrate of potash and soda. (*Part* iii.)
7. *Citric acid.* (*Ibid.*)

f. BITUMENS. (*Part* ii.)

g. SOAPS. The true nature of these compounds has been illustrated by Chevruel. He found that the fatty matter they contain consists of two distinct substances, which he has named *Steärin* and *Eläin*. These, by the action of salifiable bases, are converted into two acids, the *margaritic* and the *oleïc*; and soaps are merely combinations of one or both of these acids, with alkaline, earthy, or metallic bases. The

[1] *Annals of Phil.* vol. v. p. 99. [2] See *London Med. Repository*, vol. iii. p. 382.
[3] Berzelius.

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.)
2. *Soft soap.* (*Ibid.*)
   Variety. *Liniment of ammonia.* (*Part* iii.)
3. *Liniment of lime-water.* (*Ibid.*)

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.) It is soluble in nitric acid, and yields oxalic acid. When treated with chlorine, sugar is changed into malic acid.
   Varieties. a. *Sugar of figs,*—found concrete on the outside of the dried fruit.
   b. *Sugar of grapes,*—found crystallized in some kinds of raisins. When artificially extracted from the juice of the grape, it is white and crystallized, but less sweet than common sugar.
   c. *Sugar from starch:*—its crystals are small spherical granules. When dissolved in water, it ferments with the addition of yeast.
   d. *Mushroom sugar:*—its crystals are four-sided prisms, with square bases; very crystallizable: digested with nitric acid it yields abundance of oxalic acid.
   e. *Manna?* besides common sugar, contains mucilage, and a nauseous substance to which it owes its purgative properties. When digested with nitric acid, it yields saclactic as well as oxalic acid. It does not ferment like sugar.
2. *Sarcocoll* is usually in oblong, semi-transparent, yellow globules, which have a bitter sweet taste, and an odour resembling in some degree that of anise seed. It does not 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.)
   Officinal. Acacia Gum.
   Varieties. a. *Gum Senegal,*—in larger masses than gum arabic, and darker coloured. It is often mixed with gum arabic.
   b. *Gum kutcera,*—in loose wrinkled transparent drops, inodor-

ous, and insipid; scarcely soluble in cold water, but completely so in boiling water.

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

Officinal. 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.) With nitric acid it yields saclactic, malic, and oxalic acids.

Officinal. Tragacanth.

Varieties. a. *Cherry-tree gum*,—partially soluble only in water. When treated with nitric acid, it yields saclactic acid.

b. *Congo gum?*

c. *Dominica gum*,—in large masses like stalactites, brittle, light yellowish brown, translucent. It contains three parts of cerasin and one of gum.

5. *Ulmin*[1]. 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.

Officinal. Elecampane root.

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

Varieties. a. *Potatoe starch* has a perceptibly crystallized aspect, is more friable and heavier than common starch.

b. *Indian arrow root* has all the properties of common starch.

c. *Sago*, in grey granules. It is the prepared pith of a palm, the *Cycas circinades*.

d. *Casava*, prepared from the roots of the Iatropha Manihot.

e. *Salep?* from the bulb of the orchis mascula.

f. *Tapioca*, in granules.

All these varieties of starch are very nutritive, and excellent food for the sick and convalescent.

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. M. Taddei has ascertained that it may be decomposed into two principles — which he has named *Gliadine* and *Zimome*. When gluten is rubbed with powdered guaiaic, a blue colour is evolved. When treated with nitric acid it yields oxalic acid.

[1] So named by Dr. Thomson.

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 putrifies.

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

Officinal. Rhatany root, Galls, Uva ursi, Tormentil, Rhubarb, Cinchona barks, Swietenia, Simarouba, Kino, Catechu, Willow bark.

12. *Wax* is a fixed oil, saturated with oxygen. (*Part* ii.)

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

14. *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.

15. *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.

16. *Cathartine* is the active purgative principle of Senna. It is uncrystallizable, of a reddish yellow colour; has a bitter nauseous taste, a peculiar odour; and becomes moist in the air. It is insoluble in ether but soluble in alcohol and water in all proportions.

Officinal. Senna leaves.

17. *Resins* are brittle, semi-transparent, 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 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 when treated with it, in yielding oxalic acid, and no tannin. (See *Part* ii.)

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19. *Hematin* is the colouring matter of Logwood. It is procured in small brilliant crystals of a reddish white colour. Their taste is bitter, acrid, and slightly astringent. They form an orange red solution with boiling water; alkalies in excess change them first to purple, then to violet, and, lastly, to brown; and the hematin is decomposed. (See *Part* ii.)

Officinal. Logwood and its extract.

20. *Emetina.* This substance is obtained from Ipecacuanha and some other roots, which have an emetic property. It is, when pure, in the form of white scales, inodorous, but having a bitter and slightly acrid taste. It is not very soluble in water and alcohol, but is soluble in acetic acid, and all the other acids froming salts. It is insoluble in ether. Nitric acid converts it into oxalic acid. Half a grain, when swallowed, excites full vomiting.[1]

Officinal. Ipecacuanha root.

21. *Cinchonia*, an alkaline salt obtained from the bark of Cinchona *lancifolia*. It is inodorous, has little taste unless it be dissolved in alcohol; is white, translucent, and crystalline. It is scarcely soluble in water, ether, or oils, but very soluble in alcohol. It unites with all the acids forming soluble salts.

22. *Quina*, an alkaline salt procured from the bark of Cinchona *cordifolia*. Inodorous, very bitter, white, little soluble in water, very soluble in ether. Combines with acids forming soluble salts.

23. *Picrotoxa*, is procured from the fruit of Menispermum *cocculus*, in white, four-sided prismatic crystals; of an intensely bitter taste, soluble in twenty-five times their weight of water, and in three times their 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.

24. *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.

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[1] To obtain *Emetin*, treat powder of Ipecacuanha with ether at 63°, 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. Dissolve the reddish residue which will be obtained in 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.

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It acts with great energy on the animal economy. (See *Part* ii.)

Officinal. Opium, lactucarium.

25. *Aconita*, an alkaline substance procured from the Aconitum *Napellus*, on which the poisonous qualities of that plant are supposed to depend. (See *Part* ii.)

Officinal. Aconitum *Napellus* and its extract.

26. *Atropia*, an alkaline substance, on which the poisonous and active properties of Belladonna depend. (See *Part* ii.)

Officinal. Atropa *Belladonna* and its extract.

27. *Delphia*, an alkali, the active principle of Delphinium *Stavisagria*. (See *Part* ii.)

28. *Hyosciama*, an alkali, the active principle of Hyoscyamus *niger*. (See *Part* ii.)

29. *Veratria*, an alkali, the active principle of Veratrum *album*, and Colchicum *autumnale*. (See *Part* ii.)

30. *Strychnia*, an akaline substance, the active principle of nux vomica. It is white, granular, inodorous, extremely bitter, insoluble in ether, slightly soluble in cold water, but very soluble in alcohol. Forms a class of salts with acids; which are most virulent poisons.

31. *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,

32. *Gum resins* resemble resins in their appearance; but they are odorous, and 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, assafœtida, myrrh, sagapenum, gamboge, aloes.

33. *Wood*, which forms the support of all vegetables, is composed of tastless 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.)

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, the strong acids, many metallic oxides, and tannin, also coagulate the solution.

Officinal. White of egg, hartshorn shavings.

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3. *Solid oils* are composed, like the other fixed oils, of a solid and a fluid substance, which Chevreul has named *Steärin* and *Eläin*.
   Varieties. a. *Spermaceti*. (*Part* ii.)
   b. *Fat* is an odorous, insipid, white crystal line 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.
   Officinal. Lard, mutton, suet, fat.
4. *Cantharidin* is the active principle of Spanish flies. (See *Part* ii.)
   Officinal. Lyttæ.
5. *Cochinilin* is the colouring principle of the Cocus *Cacti*. (See *Part* ii.)
6. *Castor*. (*Ibid.*)
7. *Musk*. (*Ibid.*)
8. *Bones* and *Shells*. (*Ibid.*)
9. *Horn*. (*Ibid.*)

COMBINATION OF SOLIDS WITH SOLIDS.

Although solid bodies may be made to enter into combination with one another, 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 under any circumstances.

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 those resulting from the union of sulphur and phosphorus, which are 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

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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 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.
Acid 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[1], some acids, and a few hydrates of metallic oxides:" 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, the earths, and the 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. Thomson[2] 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 exhibits the composition of the sulphurets of the officinal metals. The first column gives the specific gravity of the sulphuret; the second the weight of sulphur united to 100 parts of the metal; the third the colour of the sulphuret.

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[1] These are alkalies in the crystalline form, or containing water solidified.
[2] *System of Chemistry*, 4th edit. iii. 136.

Metals.	Specific gravity.	Weight of sulphur combined.	Colour.
Silver - -	7·215	14·544	black
Bismuth		22·52	blue
		45·	blue
Arsenic -	3·3384	71·42	red
Copper -		25·	black
Mercury	8·16	8·2	black
		16·	red
Tin - - -		27·1	blue
		54·2	yellow
Lead - -	7·602	15·384	white
		30·768	white
Antimony	4·368	33·333	leaden-grey
Iron - -	4·518	57·1	bronze
	4·5	114·2	yellow

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 alkalies, 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 alkalies 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 or more atoms of the acid with one of the base; and the latter, which are named *sub-salts*, of two atoms

[1] Vauquelin.

of the base with one of the acid. [1]Thus supertartrate of potass consists of one atom of potass united to two of tartaric acid, or by weight, of 5·23 parts of base, and 100 of acid [2]; while carbonate of potass consists of two atoms of potass 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 potass and soda, to form the tartrate of potass and soda.

The metalline salts are seldom neutral, having generally an excess either of acid or of 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, as we have explained, are 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 gravity; 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, which is supposed to be spherical, is such, that they can move freely among each other without altering these dis-

[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.

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tances. It is this which seems to constitute the real cause of liquidity."

All liquids may be arranged into two great classes. "The following Table[1] exhibits a list of almost the whole of them, arranged according to their composition: —

I. SIMPLE.

	Sp. grav.
Mercury. (*Part* ii.)	13·568

II. COMPOUND.

a. Simple gases combined.

Water	1·000
Nitric acid. (*Part* iii.)	1·583

b. Gases with a solid base.

Sulphuric acid. (*Part* ii.)	1·898
Alcohol. (*Part* iii.)	0·794
Ethers. (*Ibid*)	0·632 to 0·900
Volatile oils. (*Ibid.*)	0·792 to 1·094
Fixed oils. (*Ibid*)	0·913 to 0·968
Petroleum. (*Part* ii.)	0·730 to 0·678
Supersulphureted hydrogen	——
Oxymuriate, or Bichloride of tin	——

c. Solids combined.

Phosphuret of sulphur	——
Sulphuret of carbon	1·272

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, under a pressure of 28 inches of mercury, 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 gases[2], 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

[1] *Thomson's Chemistry*, 5th edit. iii. p. 82.

[2] 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; $\frac{1}{27}$ of oxygen gas, nitrous gas, and carbureted hydrogen; and $\frac{1}{4}$ of carbonic oxide, azotic gas, and hydrogen gas.

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of hydrogen.[1] 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.

Supersulphureted hydrogen is a transparent colourless liquid 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, or bichloride 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 white colour crystallized appearance, and exceedingly inflammable. Its components are 100 parts of sulphur, and 75 of phosphorus.

Sulphuret of carbon is a transparent colourless liquid, having an acrid pungent, slightly aromatic taste, and fœtid 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 ONE ANOTHER.

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

I. TABLE *of liquids which unite when mixed together in all 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

[1] Biot and Arago.

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 is 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 completed, the compound is homogeneous, and the liquids do not afterwards separate from one another.

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. If fixed and volatile oils be mixed, the temperature is not very sensibly raised; but if alcohol and water are mixed, the evolution of heat is very sensible; and 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 $\frac{1}{12}$; and when water and pure alcohol are mixed, it is rather more than $\frac{1}{28}$ 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.
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 the odour of the oil to the water, without any other of its properties. Although alcohol unites readily with the volatile oils, yet the quantity of each is limited: and the proportion of petroleum which alcohol dissolves is very small. The proportions of volatile oils and petroleum which ether dissolves are considerable.

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The affinity of the compounds of this table is much weaker than those of the former; which, "with the difference between the cohesion of the particles of the two liquids, limits 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.
Mecury 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 is decomposed by phosphuret of sulphur.
Nitric acid by all liquids, except water and sulphuric acid.
Sulphuric acid by all 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.

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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 in some cases crystals.
4. *Alkaline hydrates* are what are commonly termed the crystals of alkalies.
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 one another 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 at 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 accompanied by the usual phenomena of 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 separates 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°.[1] 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.

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[1] The salts were generally in a 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.	Sulphate of Soda.	Sulphate of Potash.	Alum.	Weight of Salt in 100 parts of the Solution.	Sulphate of Magnesia.	Sulphate of Iron.	Sulphate of Zinc.	Sulphate 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	1·1515
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.	Hyper-oxymuriate 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	

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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	1·0283	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	1·0269
6	1·0358	1·0480	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	1·0837	1·1080	—	—	1·0930	1·1179
22	1·1389	1·1740	1·0863	1·1032	1·1196	—	—	1·1031	1·1307
24	1·1520	1·1928	1·0948	1·1153	1·1317	—	—	1·1135	1·1438
26	—	—	1·1045	1·1283	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				

It is necessary to keep in view, that the solvent powers of water are augmented by an increase of temperature, and that the proportions in the foregoing Tables are such as take place only at a temperature of 55°.

If a new substance be added to the saturated aqueous 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-dissolved solid being lost or precipitated: thus a saturated solution of nitrate of potash at 51° can dissolve more muriate of soda than can be dissolved by 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 is possessed by either of them in a separate state.

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

d. The actions of *petroleum*, *volatile oils*, and fixed oils, have been too little investigated to permit any general deduction.

e. 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; the force of which, according to Newton, is always inversely, as the distance of their centres 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 yet attained, nor any abstraction of caloric, can alter the constitution of air; but by compression several of the gases may be reduced to liquids, and by the simple abstraction of caloric all the vapours can be reduced to the liquid, or even the solid state.

Arrangement of the known gases according to their composition.

I. SIMPLE GASES.

1. Oxygen.
2. Hydrogen.
3. Azote.
4. Chlorine.
5. Sulphur vapour.
6. Iodine vapour.

II. COMPOUND GASES.

a. Simple gases combined.

7. Hydriodic acid.
8. Protoxide of chlorine.
9. Protoxide of azote.
10. Deutoxide of azote.
11. Muriatic acid gas.
12. Ammonia.
13. Steam.

b. Oxygen and a solid base.

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

c. Hydrogen and a solid base.

18. Cyanogen.
19. Olefiant gas.
20. Carbureted hydrogen.
21 Sulphureted hydrogen.
22. Hydroguret of phosphorus.
23. Bihydroguret of phosphorus.

d. Fluorine, Chlorine, Cyanogen, with a base.

24 Fluoboric acid.
25 Chlorocyanic acid.
26. Hydrocyanic (*Prussic*) acid.
27. Chlorocarbonic acid.

e. Two solid bases.

28 Sulphuret of carbon.

f. Triple or quadruple compound gases.

29. Hydriotic ether.
30. Chloric ether.
31. Sulphuric ether.
31. Muriatic ether.
33. Vapour of alcohol.
34. ——— of oil of turpentine.

[1] *Thomson's Chemistry*, 4th ed. iii. 437.

All these gases are invisible, except chlorine and the protoxide of chlorine, which have a yellowish green 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 barometrical pressure of* 30°.

	Specific Gravity.	Weight of 100 cubic Inches.		Specific Gravity.	Weight of 100 cubic Inches.
Air	1·000	30·5	Cyanogen	1·804	55·028
Oxygen	1·111	33·888	Olefiant Gas	0·974	29·720
Hydrogen	0·0694	2·117	Carbureted hydrogen	0·555	16·99
Azote	0·9722	29·652	Hydroguret of Phosphorus	0·9022	27·517
Chlorine	2·500	76·250			
Sulphur vapour	1·111	33·888	Bihydroguret of Phosphorus	0·9716	29·634
Vapour of Iodine	8·678	264·679			
Hydriodic Acid	4·375	133·434	Fluoboric Acid	2·3709	72·312
Protoxide of Chlorine	2·440	74·420	Chlorocyanic Acid vapour	2·152	65·636
Protoxide of Azote	1·5278	46·598			
Deutoxide of Azote	1·0416	31·769	Hydrocyanic Acid vapour	0·9368	28·572
Muriatic Acid	1·284	39·162			
Sulphureted hydrogen	1·180	35·890	Chlorocarbonic Acid	3·472	105·896
Steam	0·625	19·062	Hydriodic Ether	5·475	166·987
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 vapour	5·013	152·896
Sulphuret of Carbon vapour	2.6447	80·663			

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 sulphuric acid, 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 is therefore undetermined whether gases can 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.

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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; and even some of those bodies which are regarded as real gases, such as ammonia and chlorine, are reduced by pressure at a low temperature 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.

1. 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 almost all the other gases.

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

Oxygen with chlorine, iodine, hydrogen, azote, carbonic oxide, sulphurous acid, and protoxide of azote.

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 phosphorus, 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 in the mixture, every portion of it containing exactly the same proportion of each of the mixed gases, and when once mixed they 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 occu-

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pies 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; and that this is actually the case appears from the experiments of Mr Dalton[1], who found that two gases of different specific gravity, when merely brought into contact, the lightest being placed uppermost and the heaviest undermost, will mix together spontaneously, if left at rest; and the same effect will take place if the gases be put in separate vessels, communicating with each other by a tube only, as in the experiments of M. Berthollet[2], who supposes that the gases dissolve one another, while Mr. Dalton conceives that they are merely mechanically combined.

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, which it could not otherwise support, without being condensed. 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 some of the gases which unite by simple mixture, and form pharmaceutical products.*

Names and proportions of the gases. Volumes.			*Products.*
Oxygen	100 + 133	Nitrous gas	Nitric acid.
	100 + 200		Nitrous acid.
Ammoniacal gas with vapour			Liquid ammonia.
———	100 + 100	muriatic acid gas	Muriate of ammonia.
———	100 + 100	carbonic acid ...	Carbonate of ammonia.
———	100 + 100	sulphureted hydrogen	Hydrosulphuret of ammonia.

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

[1] *Phil. Mag.* xxiv. 8. [2] *Statique Chimique.* i. 274. 487.

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.

e. The combination of *ammoniacal gas* with sulphureted hydrogen in equal volumes, forms also a solid compound.

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

Names and proportions of the gases.				*Products.*
Oxygen	100 + 200	hydrogen		Water.
———	50 + 100	carbonic oxide		Carbonic acid.
———	250 + 100	azotic gas		Nitric acid.
———	250 + 100	chlorine		Chloric acid.
———	50 + 100	sulphurous acid		Sulphuric acid.
———	200 + 100	protoxide of azote		Nitric acid.
Hydrogen	100 + 100	chlorine ...		Muriatic acid.
	100 + 100	cyanogen		Hydrocyanic acid.
	100 + 100	iodine		Hydriodic 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 or 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. 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, as displayed in the following table.[1]

Constituents.	Volumes of ditto.	Products.	Volumes of Products.	Volumes condensed.
Hydrogen . .	1	Water	2	1
Oxygen . . .	2			
Oxygen . . .	1	Carbonic acid	2	1
Carbonic acid .	2			
Oxygen . . .	2.5	Nitric acid	1?	2·5?
Azote	1			
Oxygen . . .	1	Sulphuric acid	1·2	1·8
Sulphurous acid	2			
Oxygen . . .	2	Nitric acid	1?	2?
Protoxide of azote	1			
Hydrogen . .	1	Muriatic acid	2	0
Chlorine . . .	1			
Hydrogen . .	1	Hydriodic acid	2	0
Iodine . . .	1			
Hydrogen . .	1	Hydrocyanic acid	2	0
Cyanogen . .	1			

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

Oxygen with ..... Phosphureted hydrogen.
Chlorine with ..... Ammonia.

[1] This Table is copied from that drawn up by Dr. Thomson (*Sys. of Chemistry*, 5th edit. iii. 47.)

Chlorine with ..... Phosphureted hydrogen.
——— ..... Carbureted hydrogen.
——— ..... Olefiant gas.
——— ..... Sulphureted hydrogen.
——— ..... Nitrous gas.
Sulphureted hydrogen with ... Nitrous gas.
——— ... Sulphurous acid.

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 hydrophosphorous acid; but when it is complete, they are water and phosphoric acid.

b. *Chlorine* and *ammonia*, when brought into contact, excite spontaneous combustion; one fourth of the ammonia is decomposed; the hydrogen of that portion uniting with the chlorine, and forming muriatic acid, which enters into combination with the remaining ammonia, whilst the azote is dissipated.

c. *Phosphureted hydrogen gas*, when mixed with chlorine, burns, and exhibits a lively combustion. The products are bichloride of phosphorus and common muriatic acid.

d. *Chlorine*, when mixed with the heavy inflammable gases, does not occasion combustion, but slow and imperceptible decomposition takes place.

e. *Chlorine* with nitrous gas has no reciprocal action: it is brought to the state of common muriatic acid; while the nitrous gas is converted into nitric acid. The requisite proportions, according to Humboldt,[1] are equal bulks of each gas.

f. *Sulphureted hydrogen gas* and *nitrous gas* mixed together in a dry state suffer spontaneous decomposition; sulphur is deposited, and protoxide of azote, 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.* tom. xxviii. p. 142.

Oxygen with vapour of ether.
——————— alcohol.
Nitrous oxide with hydrogen.
——————— phosphureted hydrogen.
——————— sulphureted hydrogen.
——————— carbonic oxide.
——————— carbureted hydrogen.
——————— olefiant gas.
——————— vapour of ether.
——————— alcohol.
Nitrous oxide with 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 are 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,

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the products will be 4·6 inches of carbonic acid, and a portion of water.

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 which is 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 phosporic 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.

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

[1] *Thomson's Chemistry*, 4th edit. iii. 469.

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

The quantity of any gas absorbed by water is very much increased by pressure; but by diminishing 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 aëriform 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 the temperature are equal, it then "absorbs a determinate quantity of every individual gas."

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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 Mr. Saussure.*[1]

Names of Gases.	Bulk absorbed by 100 cubic inches of water, according to		
	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 first three gases; one-eighth of its bulk of the fourth; one-twenty-seventh of the fifth, sixth, and seventh; and one-sixty-fourth of the last three; 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 aërated 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 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 aërated water must be preserved in well-stopped bottles; or under an atmosphere of the same gas it contains.

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

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

TABLE *of the very absorbable gases, with the numbers of measures of each absorbed by one measure of pure water*[1] *! and the increase of bulk produced on the fluid, supposing the original bulk to be* 1.

Names of gases.	Measures absorbed.	Bulk in cubic inches.
Chlorine	2	1·002
Cyanogen	4¼	
Sulphuris acid	43·78	1·040
Fluosilic acid	363	——
Muriatic acid	516	1·500
Fluoboric acid	700	——
Ammoniacal	780	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; but the experiments of Saussure render it probable, that alcohol and oil absorb a much greater proportion than water.

3. OF THE COMBINATION OF GASES WITH SOLIDS.

From the difference which exists between the constitution of gases and solids, their combination appears to be opposed by 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*, *chlorine*, *hydrogen*, *azote*. Of these oxygen combines with all the known simple solids; which are *carbon*, *boron*, *silicon*, *phosphorus*, *sulphur*, and the *metals*; hydrogen requires that the solids be brought into a fluid state before it can combine 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: thence, 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;

1 *Thomson's Chemistry*, 5th edit. iii. 68.

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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 *hypophosphorus acid*, *phosphorus acid*, and *phosphoric acid*, which are all solid substances. The proportions of the constituents of these three compounds are the following: hypophosphorus acid consists of 100 of phosphorus and 66·6 of oxygen, or one atom of phosphorus and one of oxygen: phosphorus acid of 100 of phosphorus and 133·3 of oxygen, or of one atom of phosphorous 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; 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 thence 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 one another, and exerting various degrees of medicinal power.

b. Chlorine forms two compounds with phosphorus, one liquid and the other solid; and one compound, which is liquid, with sulphur. It unites with all the metals forming solid compounds.

c. 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, 1. *olefiant gas*, which is composed of one atom of carbon and one of hydrogen; 2. *carbureted hydrogen*, composed of two atoms of hydrogen and one of carbon; and 3. *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.

d. 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.

[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

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 integral parts: the second are intended for separating the elements of bodies from one another, 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

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, solubly in water and alcohol; and highly inflammable.

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 prescriptions, for denoting the different weights.

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

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

Troy or Apothecaries' weight.

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

Avoirdupois weight.

Pound.		*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 symbols used for denoting the several measures.

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.

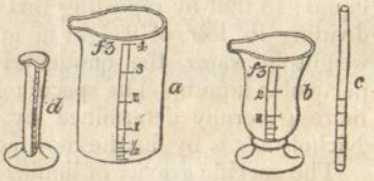
A gallon (*congius*), Cong. or c	contains	Eight pints.
A pint (*octarius*), O		Sixteen fluid ounces.
A fluid ounce (*fluid uncia*), f ℥		Eight fluid drachms.
A fluid drachm (*fluid drachma*), f ʒ		Sixty minims.
A minim (*minimum*), ♏		

Table of the proportions of the wine gallon.

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

The London College have introduced the minim 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 the size of the drop; but by dividing the fluid drachm into sixty equal parts, a measure of bulk is obtained, which is as constant and uniform as the grain weight employed as solids.

For measuring liquids graduated glass measures of different sizes *a*, *b*, are to be preferred: and for quantities under five minims a slender graduated glass tube, *c*, 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. A small glass measure, properly graduated, is now pretty generally used instead of the tube. In extemporaneous prescriptions, 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.

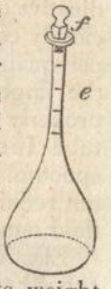


Elastic fluids or gases are also measured in glass jars, or tubes hermetically closed at one extremity, and graduated by inches with their decimals; but, in ascertaining the bulk of gases, the temperature of the atmosphere, and its density at the time, as indicated by the thermometer and the barometer, 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 it is 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 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."[1] 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 hair or a fine platinum wire, be weighed first in air, and afterwards in distilled water, of the temperature of 60°, Fahr., 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, *e*, and holds about a fluid ounce or two fluid ounces of water, and stop its neck by a piece of barometer-tube very accurately ground; or a conical stopper with a notch in it, *f*. First weigh the empty bottle and tube, then fill it with distilled water at 60°, recently boiled, till the water rises a little into the bore of the tube, and weigh the whole, scratching the weight in grains on the bottle, and also the weight in grains 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. A bottle of this kind is now sold under the name of "*Thousand grain bottle*," with a weight which is an exact counterpoise to it, when it is full of distilled water at 60°.



1 *Lavoiser's Elements of Chemistry.* — Trans. 376.
2 *Nicholson's Journal*, 4to.; 110.

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DFG

By filling this bottle with any 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] Thus, if it be filled with sulphuric ether, instead of weighing 1000, it will require 739 grains to be put into the scale with the bottle to restore the equilibrium, and thence, its sp. gr. is 0·739: but, if sulphuric acid be used, 875 grains will be required to be added to the 1000 grains weight in the opposite scale, and consequently its sp. gr. is 1·875.

In ascertaining specific gravity the substances should be brought by calculation to the temperature of 60°, 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. Sikes' hydrometer is the one employed by the Excise. 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 Sikes' 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.*

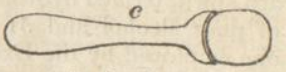
The cohesion of solid bodies often opposes an obstacle to their immediate chemical combination with other substances, and their medicinal action in the stomach; and therefore the following preliminary mechanical operations are instituted for overcoming to a certain degree that power, and separating the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

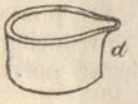
1 *Aiken's Dictionary of Chemistry*, ii. — *Appendix.*

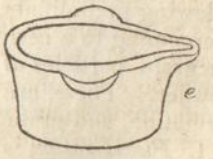
porcelain, or of Wedgewood's ware, according to the nature of the substances for the pulverization of which they are intended to be used; it being requisite that the materials of which pestles and mortars are made be such as to resist both mechanical force and the chemical action of the substances they contain. Thus a mixture containing any astringent matter, is turned black if rubbed in an iron mortar.

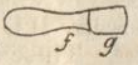


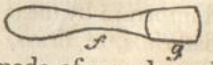


Mortars are required to be of various sizes. The largest size is usually made of cast-iron, *a*. fitted with a wooden cover, *b*. perforated to admit the pestle, but close enough to prevent the finer and lighter parts of the substances from flying off, and to defend the operator from disagreeable and noxious matters, such as aloes, ipecacuanha, &c. This may be more completely attained by tying closely round the mouth of the mortar, and round the stalk of the pestle, *c*. 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 arise 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 porcelain and Wedgewood's ware, *d*. *e*. as they are smooth, hard, and resist the action of any chemical reagent. The handles, *f*. of the pestles are made of wood, and the heads, *g*. of the same material as the mortar.









Of whatever materials mortars are made, they should be internally, at bottom, 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.

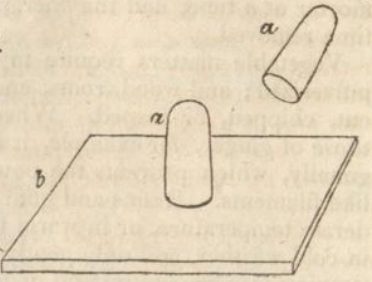
Vegetable matters require to be dried before they can be pulverized; and wood, roots, and barks should be previously cut, chipped, or rasped. When roots are very fibrous, as those of ginger, for example, it is advisable to cut them diagonally, which prevents the powder from being full of hair-like filaments. 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 metals may be rendered brittle by alloying them with a small quantity of mercury[1];" but as metals are not required to be reduced to the state of very fine powder for pharmaceutical purposes, these processes are seldom performed.

2. *Trituration* is intended to produce the same effect as pulverization, but in a greater degree. It is performed by a rotatory motion of the pestle, either in the common mortars of glass, agate, or Wedgewood's ware, or in flatter mortars made of the same materials. On a great scale, this operation is performed by means of large rollers of hard stone, which turn upon each other as in corn-mills, or by one vertical roller turning upon a flat stone. The fine powders kept in the shops are generally ground in this manner; but there appears to be an error in reducing vegetable matters to the state of impalpable powder: for in this state, both during the process of grinding and afterwards, the air and light act powerfully upon

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

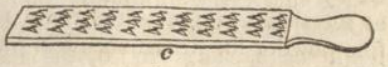
them, and produce changes, which, although they be not well understood, yet appear to alter the medicinal virtues of the substances.

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 on a flat table of porphyry, or some other hard stone, *b*. and is then bruised and rubbed with a muller of the same materials, either of a pyramidal shape, as *a a*. 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 until it is cold, or pouring it, in the melted state, into water, and stirring or agitating it till it cool. For the granulation of phosphorus the latter process must be employed.

Substances are also reduced to the state of coarse powder by rasping and filing; and softer vegetable bodies are converted to a pulp by means of the grater, *c*.



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. For this purpose sieves are employed, made of iron-wire, or of hair-cloth, or of gauze. These permit the finer particles to pass through them, and leave the coarser to be again submitted to the pestle; and thus by de-

grees the whole assumes 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, *b*, with a deeper rim, *a*, a lid covered with leather, and *d*, a receiver, 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 still containing the finer particles suspended 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 drawing it off through the glass syphon, *g*, the longer limb of which being plunged into the vessel containing the fluid till it nearly touches the subsided powder, where it is supported by the board, *f*, placed on the mouth of the vessel, *e*, and the air sucked from it by means of the arm, *h*, the whole of the supernatant fluid is drawn off into the vessel, *i*, and the powder left in a fit state to be dried.[1] 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.



[1] The fluid may also be drawn off by means of wet cotton or worsted threads, having one end in the fluid, nearly touching the precipitate from which it is to be separated, and the other hanging over the side of the vessel, below the plane of the fluid in it.

3. *Filtration* is intended for separating fluids from solid bodies suspended in them. Filters may be regarded as kinds of sieves; and are generally made either of very fine and close flannel, or of 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 suspended in the fluid is not in the state of very fine powder, 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 obtained, also, in a more limpid state. The cloth must be well cleaned after every time that 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 a second doubling forms again a smaller triangle, and this when opened constitutes a paper cone, *k*, which is to be supported in a glass funnel, *l*, before the liquor is poured into it.



Funnels are made of tin, or of Wedgewood's ware, or of glass; but only the two latter 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 quills, 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 therefore require to be poured back again into the filter, sometimes repeatedly, until the pores are sufficiently obstructed to permit the most limpid part only of the liquor to pass. 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; and blown to a globe in the center; by filling which with distilled water, and putting the larger end into the mouth, the force of the breath can direct a small, but 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 materials commonly employed for filters, to be filtered in the ordinary 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.

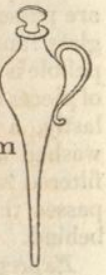
Expression is employed for obtaining the juice of fresh vegetables, and the unctuous vegetable oils. The subject is first bruised or coarsely ground, then inclosed in a hair-cloth bag, and subjected to violent pressure between the plates of a screw press. The bags should be nearly filled; and the pressure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

Vegetables in general, intended to be expressed, should be perfectly fresh, and cleansed from all impurities; 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 a 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 which 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 syrup, 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, 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 one another, fluids of different specific gravities, mixed together, are separated by means of the separatory funnel, *m*. It is chiefly used for separating the essential oils from the water with which they are entangled 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 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 oxidizement and the deoxidizements of bodies are effected by means of a very high temperature.

a. Of the operations which produce changes in bodies, separating the constituents, without any obvious decomposition.

These changes are effected —

1. By caloric — inducing . . Liquefaction.
   Fusion.
   Evaporation.
   Exsiccation.
   Distillation.
   Rectification.
   Dephlegmation.
   Sublimation.

2. By water and other fluids.	Solution.
	Lixiviation.
	Maceration.
	Digestion.
	Infusion.
	Decoction.
	Extraction.
3. By other chemical agents -	Coagulation.

1. *Operations in which the changes are effected by caloric.*

Liquefaction is that operation by which certain bodies when exposed to a moderate heat are rendered fluid, after passing through several intermediate states ofsoftness. Fat, lard, wax, resin, and many other similar bodies undergo liquefaction; which is, therefore, employed in pharmacy to facilitate the combination of these bodies in the formation of ointments. The best vessels for conducting the process of liquefaction are earthen ware pans.

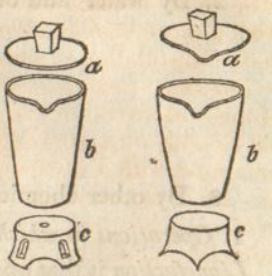
Fusion differs from liquefaction, in the sudden change from the solid to the fluid statewhich those bodies, which are liable to it, suffer on exposure to heat. There are no intermediate states of softness; but the fusible body, when heated to a certain point, immediately assumes the fluid form. This 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 smelted 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 easily vitrified, and then melt. The Hessian crucibles are composed of better clay and sand, and when good, stand the fire very well; as do also Wedgewood's crucibles; but they are apt to crack when suddenly heated or cooled, — a circumstance, however, which may be remedied by using a double crucible, and filling the interstice with sand, or by coating the crucible with a paste of clay and sand. Crucibles formed of black lead resist very sudden changes of temperature; but, they are destroyed, if nitre be melted in them, and even a current of air acting upon them,

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whilst they are hot, destroys them. Crucibles are made of various forms, three-cornered or round, *b b*, and fitted with covers, *a a*. The lids may be luted on if necessary, with a mixture of clay and borax. Those crucibles, which are of uniform thickness, which have a reddish-brown colour without black spots, and a clear sound when struck, are to be preferred.



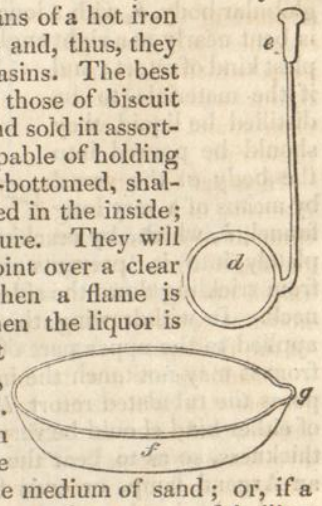
In order to expose the lower part of a crucible to the utmost intensity of heat, and to prevent it from cracking by the draught of cold air which would be directed upon it, were it to be placed directly upon the grate of the furnace, it is usually raised upon a small stand *c c*, either solid or hollow, 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 aeriform 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 mattrasses, which may be cut smooth round the edges by means of a hot iron or ring *d*, with a wooden handle *e*; and, thus, they are converted into semiglobular[1] basins. The best evaporating dishes, however, are those of biscuit porcelain made by Wedgewood, and sold in assortments, the largest of which is capable of holding eight or ten pints. They are flat-bottomed, shallow vessels, *f*, with a lip, *g*, 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, therefore, 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 should be 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.



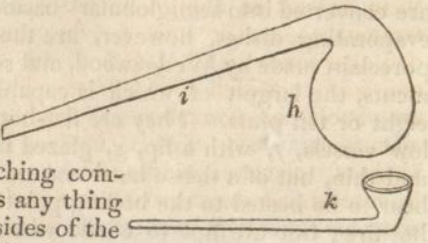
Exsiccation is a variety of evaporation, producing the expulsion of moisture from solid bodies by means of heat. It is generally employed for depriving salts of their water of crystallization. They are exposed to the action of a fire in an iron ladle or pot, or in a glass vessel; and after dissolving as they are heated, in the water they contain, or undergoing what is termed 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.

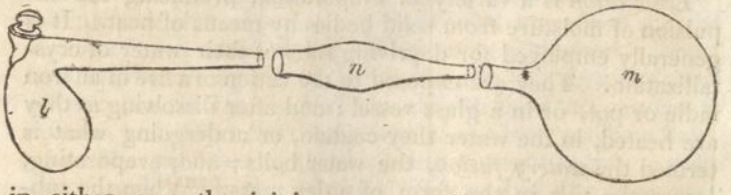
Distillation differs from evaporation only in the circumstance, that the vapour of volatile matter is elevated to be condensed

[1] The iron ring for this purpose is made red-hot in the fire, then put upon the mattrass 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.

in close 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.

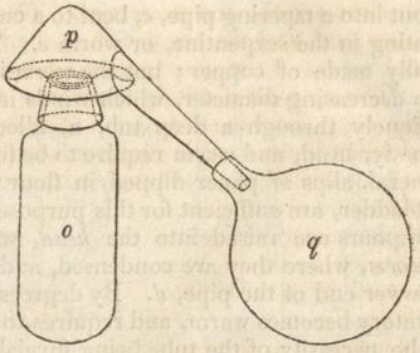
The simplest distilling apparatus, for smaller processes, is the *Retort* and the *Receiver*. The former consists of a nearly globular body, *h*, with a long, gradually tapering neck, *i*, which is bent nearly at a right angle with the body. This is the simplest kind of retort; and if the materials to be distilled be liquid, they should be poured into the body of the vessel by means of a very long funnel, *k*, which, by reaching completely into it, prevents any thing from trickling down the sides of the neck. In withdrawing the funnel, 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, *l*, is to be preferred. 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, *m*, 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, *n*, denominated an *adopter*; and



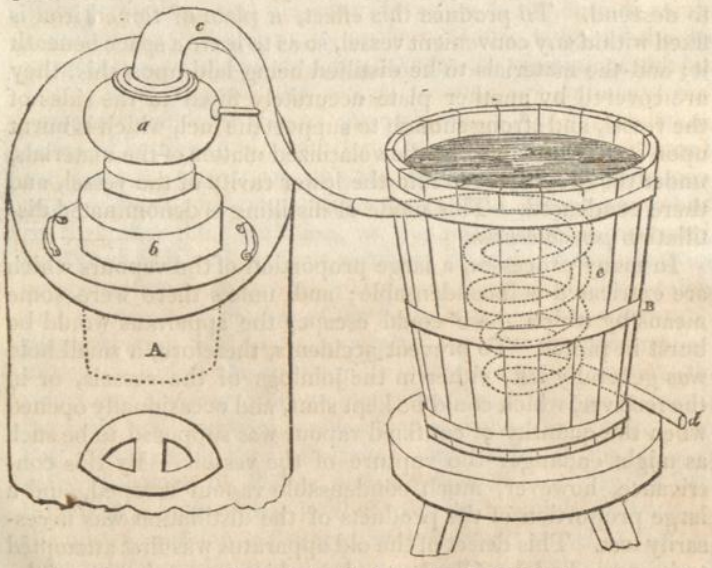


in either case the joinings are usually protected by lutes. When the substance to be condensed is of a very volatile nature, as ether, for instance, the receiver must be artificially cooled; and kept during the whole process at the temperature of the atmosphere, either by surrounding it with ice, or 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. Both the retort and the receiver may be tubulated.

Sometimes, instead of the retort and receiver, the stone-



ware cucurbit, *o*, with its capital, *p*, and receiver, *q*, is 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.

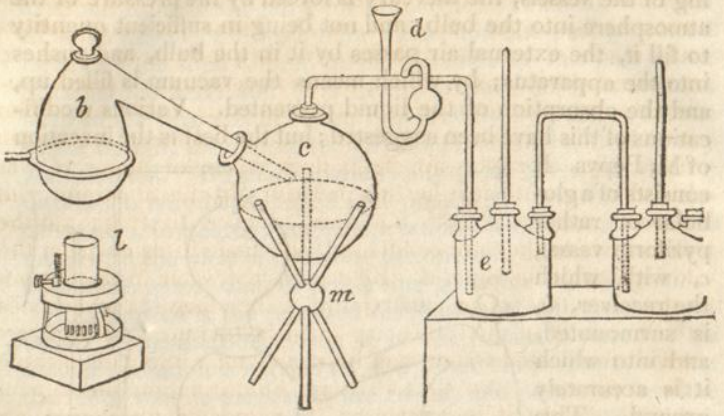


For the preparation of alcohol, and of distilled waters, the common still is employed. It consists of two parts, — the boiler, *b*, and the head or capital, *a*. The boiler, which is the part to which the fire is applied, and contains the materials, is generally of a cylindrical shape, and may be sunk into a furnace, or immersed in a water-bath, *d*, 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, *c*, bent to a curve or arch, and terminating in the serpentine, or worm *e*. 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, B, 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*, whence they pass into the *worm*, where they are condensed, and issue in drops from the lower end of the pipe, *d*. By degrees the water in the refrigeratory becomes warm, and requires to be renewed; and thence the necessity of the tube 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*.

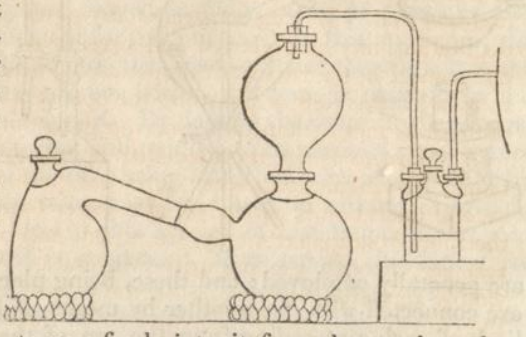
In some cases, as in the distillation of several essential oils, the vapour, instead of passing laterally, or ascending, is forced to descend. To produce this effect, a plate of tinned iron is fixed within any convenient vessel, so as to leave a space beneath it; and the materials to be distilled being 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 vapours which are 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, *b*, generally tubulated, in which the materials are heated by a lamp, *l*; a receiver, *c*, supported by a stand, *m*, 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, *e*, with two apertures, and which is about half full of water. Several bottles, however,



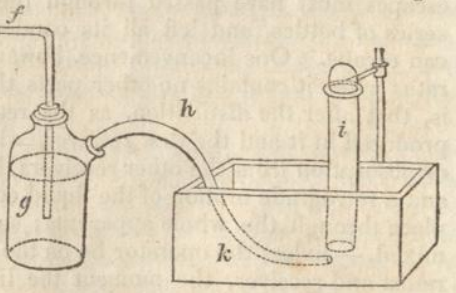
are generally employed; and these, being placed side by side, are connected with one another by means of bent tubes, one limb of each proceeding from the top of the bottle immediately preceding, and the other plunging to the bottom of the liquid of the bottle next in order. The joinings of the apparatus 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 be 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 at *d*. 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 cut, 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 cool-

ing 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. Various modifications of this have been suggested; but the best is the invention of M. Pepys. It consists of a globular or rather pyriform vessel, *c*, with which the receiver, *b*, is surmounted, and into which it is accurately ground. This is furnished with a glass valve,



which allows gas to pass freely into it from the receiver, but prevents the water which it contains from falling into the receiver.

In chemical operations, when the gases which are separated during a process are to be preserved, the pneumatic trough, *h*, with its inverted jar, *i*, under which the curved tube, *k*, proceeding from the bottle *g*, opens, is attached to Woulfe's apparatus. The construction of the trough differs according to the nature of the fluid with which it is filled.



If water be employed, the trough may be 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 the 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 extri-

cated 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 re-distilled 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 aludel, *a*, *a*, *b*, *b*, *c*, which may be extended to any number of vessels, is generally used in this operation. The product in these cases is solid, and is denominated a *sublimate*.

b. Of the operations by which chemical changes are produced in the forms of bodies by the action of water, and other fluids.

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, retaining 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; for muriate of soda, for example, and some other salts, can be 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.

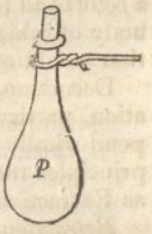
Lixiviation is a term applied to solution when the saline body consists of both soluble and insoluble ingredients. On a great scale it is generally performed in large tubs, or vats, having a hole near the bottom containing a wooden spigot and faucet. A layer of straw is placed at the bottom of the tub

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 of water 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 solution, 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 or in spirituous fluids 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, except that the power of the fluid is aided by a gentle heat. It is usually performed in a glass matrass, *p*, 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 which contains 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, or a lamp, a water-bath, or a sand-bath; and, when either of the latter are used, the matrass 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, *q*, with the neck, *r*, cylindrical, and having a very large lip or spout, *s*, 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. Decoction 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, a retort and receiver, or the common still, may be 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.

Extraction. If the liquor, which is obtained by either infusion or decoction, be subjected to evaporation, the watery part is dissipated, and the part which was extracted by it is obtained in the solid form, and is 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*.

c. *Of the operations by which changes are produced in bodies 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, alcohol, 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 another.*

These are — Decomposition,
Dissolution,
Precipitation,
Crystallization,
Fermentation.

Decomposition implies the separation of the component parts of bodies from one another. It is produced, in some cases, by heat, or the introduction of caloric into a body in sufficient quantity to separate the particles from one another to a distance beyond the sphere of the attraction of affinity which held them in combination. It may be effected, also, by electricity or galvanism; but in the greater number of instances it is the result of a superior affinity, which 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.

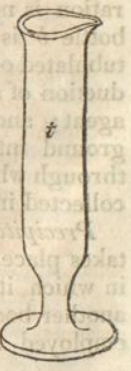
Dissolution is the appellation given to cases of solution accompanied with decomposition, or some alteration in the nature of the dissolved body. In general, the dissolution of a body is attended with considerable effervescence, owing to the extrication of gases; and therefore the operation requires to be performed in capacious vessels, to prevent the loss of the materials. When the gas is required to be preserved and the operation is not on a large scale, the proof bottle *b* is used. It is furnished with a tubulated orifice *c*, for permitting the introduction of acid or any other decomposing agent; and *a*, a curved tube, which is ground into the opening of the bottle through which the gas escapes. The gas is collected in inverted jars in a pneumatic trough.



Precipitation is an operation in which decomposition, also, 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 the solution. 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. In other cases 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 acetate 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, *t*, 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.

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 preceptible 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] All the substances not employed in Pharmacy are omitted.

	Precipitants.[2]
1. Alkalies.	
Potash	Tartaric acid.
Soda	0.
Ammonia	Fixed alkalies.
2. Alkaline Earths.	
Barytes	Sulphuric acid, sulphates.
Lime	Oxalic acid, oxalates.
Magnesia	Phosphoric acid, phosphate of soda.[3]
3. Earths Proper.	
Alumina	Ammonia, hydrosulphuret of potash.
4. Metallic Oxides.	
Silver	Muriate of Soda.
Mercury	Muriate of soda.
Copper	Iron.
Iron	Succinate of soda, benzoate of soda.
Lead	Sulphate of soda.
Zinc	0, alkaline carbonates?
Antimony	Water, *hydrosulphuret of potash.*
Arsenic	Nitrate of lead.
5. Acids.	
Sulphuric	Muriate of barytes.
Carbonic	Muriate of an alkaline earth.
Boracic	Sulphuric acid.
Nitric	0.
Acetic	0.
Benzoic	Muriatic acid.
Succinic	Sulphate of iron.
Oxalic	Muriate of lime.
Tartaric	Potash.
Citric	Acetate of lime.

In some cases, when decomposition is effected by the addition of another substance, the separated body is not precipitated, but rises to the surface, and is thence denominated a *cream:* thus, by the addition of any acid to a solution of soap,

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[1] *System of Chemistry*, 5th edit. iii. 149. — 154.

[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 muriate 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.

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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 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 either in the aëriform state or a state of fluidity, produced either by the agency of caloric or that of water.

Thus Camphor, Iodine, Arsenic, and Benzoic acid pass at once from the state of vapour into a regular crystalline form; while 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, as, for example, *sulphate of soda*, 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, in a state of combination with the salt, a considerable proportion of water, which is thence termed *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 form on its surface; when it is set aside to cool, during which the crystals form. After these are separated, the evaporation is repeated, and another crop obtained, until, by a succession of evaporations, the greater part of the salt contained in the solution is separated in the crystalline state. The same effect may be produced by spontaneous evaporation.

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

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

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, 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 Wedgwood's ware, such as have been already described (p. 87.) 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. Sometimes the crystallization, particularly when it is effected without the aid of heat, is disturbed by minute crystals forming on the edge of the vessel, and the saline matter extending itself over its sides. This is best prevented by smearing the edge of the evaporating dishes with a little oil.

Crystallization is intended to obtain crystallizable substances in a pure state; and to separate them from one another, 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 one another, and a spontaneous decomposition takes place, even at the ordinary temperature of the atmosphere. This process has been denominated *Fermentation* by chemists, on account of the intestine motion with which it is accompanied: and, as its phænomena and results vary according to the nature of the vegetable matter subjected to it, and the circumstances

under which it occurs, the general process is divided into three species easily distinguished from one another. 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 fœtid, 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, sugar, 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, accom-

[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.

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panied 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 this 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 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 thence the necessity of preparing these every day during summer, as by the decomposition which takes place, their medicinal virtues are completely destroyed, when they are kept.

Putrefactive Fermentation. Almost every vegetable product, in a moist place, and in a temperature not under 45°, nor above 70°, undergoes spontaneous decomposition. The solid structure of the body is completely destroyed, and its ultimate principles entering into new combinations, escape in the gaseous or aëriform state, leaving behind a small quantity of earthy and metallic matter only, which it 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, most readily undergo it; the surface of the liquor becomes covered with a mould; various elastic fluids, in which ammonia and phosphuretted hydrogen gas are often perceptible, with other matters which produce a fœtid odour, are extricated, and the vegetable matter 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, of exposing them in a free current of air to dissipate the humidity which they would otherwise absorb.

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

c. Of the OPERATIONS *in which oxidizement and deoxidizement are 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 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. 2dly, The chimney by which the heated air and the smoke escape. 3dly, The ash-pit, into which the ashes fall, and through holes in the side of which fresh air is admitted to the burning fuel.

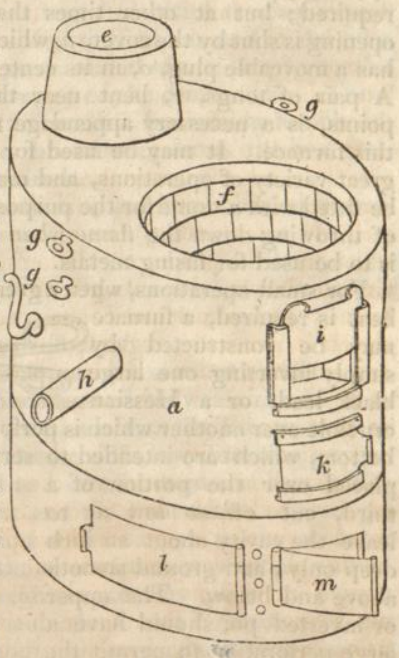
In a well-constructed furnace, the whole of the air which enters the ash-pit passes through the body of the furnace, and supports the combustion, after which the residue, being highly rarified, passes off by the chimney; on the due height of which, and the proper regulation of the access of atmospheric 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

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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, is kneaded together with water, and the mass thus formed, divided into balls of a moderate size. 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 cover the inside of the furnace, and the cavity assume an elliptical form.

A very convenient and useful furnace is that which was contrived by Dr. Black. It consists of an oval iron case, *a*, 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 having two apertures; one large, *f*, intended to receive a sand-bath, a still, or similar apparatus; and the other smaller, *e*, 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, *m*, 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 passing the sliding plate, *l*, over them either one or more may be stopped at a time, and 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, *i*, 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

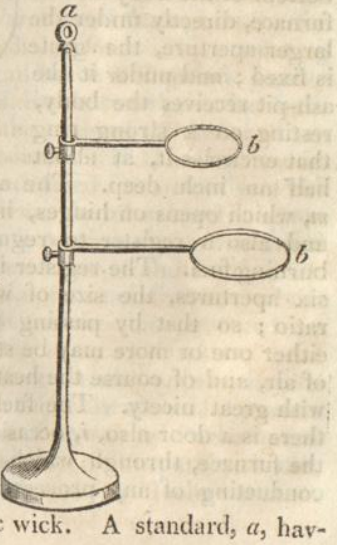


shut very close, this door is a disadvantage, as it prevents the admission of the air from being so precisely regulated. It has also an opening, *k*, with a sliding door, for receiving a muffle: *k* is an earthen or an iron tube, which passes through the body of the furnace, and issues at the opposite side, intended for procuring hydrogen gas; or for inserting the nozzle of a pair of bellows. Any thing may be suspended over the furnace by inserting an iron pillar into the eyes, *g g*, on each side, and stretching a strong bar or wire between them. The sand-bath, *n*, is placed in the opening, *f*, of the furnace when it is required; but at other times that opening is shut by the cover, *p*, which has a moveable plug, *o*, in its center. A pair of tongs, *r*, bent near the points, is a necessary appendage to this furnace. It 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, when a great heat is required, a furnace may be constructed by simply inverting one large black lead, or a Hessian crucible over another which is perforated with six holes in the bottom, which are intended to serve as a grating. This is placed over the portion of a third, cut off so low as to leave the cavity about an inch deep only; and ground smooth above and below. The upper or inverted pot should have a large perforation to permit the heated air to escape; and the portion on which the second pot stands should also be perforated at the side to admit the external air, or the nozzle of a bellows. No luting is required. A heat sufficient to fuse any metal may be obtained in such a furnace. 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. A standard, *a*, hav-



ing moveable rings, *b*, *b*, attached to it, is necessary for supporting the retort or matrass at any height above the flame.

With regard to *fuels*, the best are undoubtedly charcoal and coke, 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. *Coke* is much less expensive; but as it contains a mixture of earth 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 of air for carrying on the combustion. These disadvantages, however, are remedied by mixing it with an equal bulk of charcoal; and this mixture forms the best fuel, when an intense heat is required.

The pharmaceutical operations (usually performed by furnaces) are —

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

The three 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 the light which oxygen gas contains, by the solidification of the oxygen in the oxide, is scarcely perceptible when the operation is conducted in atmospherical air; but if the oxidizement takes place in oxygen gas, it is rapidly affected, 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 mattrass with a very tall narrow neck, the mouth of which is left open. This mattrass is placed in a sand-bath, and kept at a degree of heat nearly equal to the

boiling point of the mercury, for several days: but, it is perhaps better to use a retort with the bottom flattened, and the neck only slightly bent, that the globules of mercurial vapour may be condensed, and the metal fall back into the vessel.[1] In this process the atmospheric air furnishes the oxygen, which readily combines with the volatilized mercury, while the form of the apparatus is intended to permit a renewal of it constantly to take place, without allowing the escape of the mercurial vapour.

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

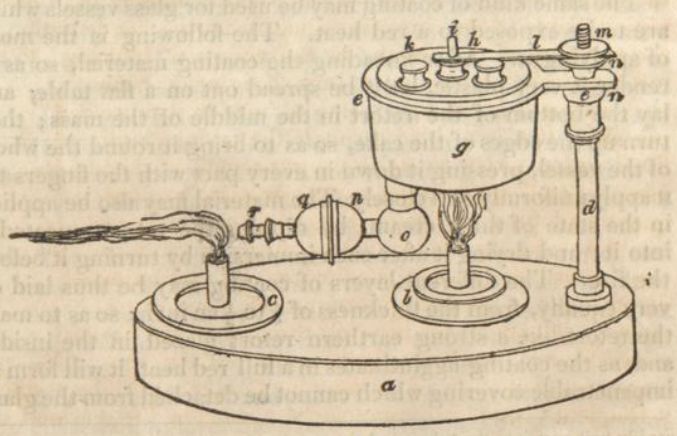


In using this apparatus with advantage and ease, a little practice is necessary. As the flame is often required to be kept up for several minutes, the respiration must be carried on through the nostrils without interruption, and the stress of blowing performed merely by the compression of the cheeks upon the air held in the mouth. In subjecting any substance to experiment, it is to be placed either on a piece of charcoal,

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

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 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 the substance or its deoxidizement. 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.[2]



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.

2 *Mr Paul's alcohol blowpipe:* *a*, A hollow frame of wood, five inches in its longest dimension, supporting the pillar, *d*, and the two lamps, *b*, *c*; the rim, *e*, slips upon the pillar, *d*, as low as the shoulder of the latter will permit; but it may be raised or lowered at pleasure, and kept fast by the screw peg, *f*. The rim supports *g*, the boiler, which is a hollow piece of thick brass, which will hold about f℥j of alcohol, and has four openings; three, *h*, *i*, *k*, at the top, and one at the bottom, to receive the tube *o*. The latter is long enough to reach the level of the outside of the boiler, and consequently the alcohol in the boiler cannot

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: thence the necessity of coatings and lutes. 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, should 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 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 apply uniformly and closely. The material may also be applied in the state of thick cream, by dipping the retort repeatedly into it; and 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 earthern 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.

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readily boil over into the tube; and the opening *k*, which corresponds with it, is closely shut by a screw stopper, hollowed out a little beneath, to allow the free passage of the vapour down the tube. By the contiguity of *o* to the lamp *b*, the vapour is prevented from condensing, and as it passes on through the globe *q q*, into the jet tube *r*, it is directly kindled by the flame of the lamp *c*; and the united flames being violently propelled sideways, a long pencil of blue flame is formed, and remains as long as any alcohol is left in the boiler. The boiler is filled at the opening *h*. The central hole, *i*, is nicely fitted with a brass plug, kept down by a thin slip of iron, *l*, which is confined at one end between two flat screws, *m*, *n*, on the top of the upright pillar. This acts as a safety valve, to prevent the vessel from bursting when the vapour cannot escape quick enough at the jet pipe *r*.

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

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

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

[1] *Lavoisier.*

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]

8. A solution of shell lac in alcohol, added to a solution of isinglass in proof spirit, forms a cement that will resist moisture.

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 feel 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 they have been 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.
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 kinds of cement for any accidental crack or failure of a lute

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

already applied, although a stream of vapour may be bursting through at the time.[1]

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

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

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 tube 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. When an operator, therefore, is not pressed for time, he should always allow the luting of one joint to dry before he applies luting to another; indeed, it is preferable not to apply the fillets and ligatures, until after the luting has been applied to all the joints; and is nearly hard.

[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 - Diluted sulphuric acid	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°.

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TABLE II.

FRIGORIFIC MIXTURES—*WITH ICE.*

Mixtures.	Thermometer sinks.	Degree of cold produced.
Parts.		
Snow, or pounded ice 2 Muriate of soda - 1	From any temperature. to −5°	*
Snow, or pounded ice 5 Muriate of Soda - 2 Muriate of ammonia 1	From any temperature. to −12°	*
Snow, or pounded ice 24 Muriate of soda - 10 Muriate of ammonia 5 Nitrate of potash - 5	From any temperature. to −18°	*
Snow, or pounded ice 12 Muriate of Soda - 5 Nitrate of ammonia 5	From any temperature. to −25°	*
Snow - - - - 3 Diluted sulphuric acid 2	From +32° to −23°	55
Snow - - - - 8 Muriatic acid - - 5	From +32° to −27°	59
Snow - - - - 7 Diluted nitric acid - 4	From +32° to −30°	62
Snow - - - - 4 Muriate of lime - 5	From +32° to −40°	72
Snow - - - - 2 Cryst. muriate of lime 3	From +32° to −50°	82
Snow - - - - 3 Potash - - - - 4	From +32° to −51°	83

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.

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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 sulp. acid 3 } *Or*, Diluted nit. 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 sulph. 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.

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No. 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	Arsenic	*Acids:*
	Bismuth	Molybdena	Arsenic
	Lead		Lactic
Carbon	Copper		Benzoic
Charcoal	Tellurium	POTASH, SODA, and AMMONIA.	Acetic
Manganese	Platina		Boracic
Zinc	Mercury		Sulphurous
Iron	Silver	*Acids:*	Nitrous
Tin	Gold	Sulphuric	Carbonic
Antimony		Nitric	Prussic
Hydrogen		Muriatic	Sulphur
Phosphorus	CARBON.	Phosphoric	Phosphorus
Sulphur		Fluoric	Water
Arsenic	Oxygen	Oxalic	Fixed oils
Nitrogen	Iron	Tartaric	
Nickel	Hydrogen	Arsenic	
Cobalt		Succinic	STRONTITES.
Copper	NITROGEN.	Citric	
Bismuth		Lactic	*Acids:*
Caloric?	Oxygen	Benzoic	Sulphuric
Mercury	Sulphur	Sulphurous	Phosphoric
Silver	Phosphorus	Acetic	Oxalic
Arsenous acid	Hydrogen	Mucic	Tartaric
Nitric oxide		Boracic	Fluoric
Gold		Nitrous	Nitric
Platina	HYDROGEN.	Carbonic	Muriatic
Carbonic oxide	Oxygen	Prussic	Succinic
Muriatic acid	Sulphur	Oil	Acetic
White oxide of manganese	Carbon	Water	Arsenic
	Phosphorus	Sulphur	Boracic
White oxide of lead	Nitrogen		Carbonic
			Water
OXYGEN. *	SULPHUR.	BARYTES.	
			LIME.
Titanium	PHOSPHORUS.	*Acids:*	
Manganese		Sulphuric	
Zinc	Potash	Oxalic	*Acids:*
Iron	Soda	Succinic	Oxalic
Tin	Iron	Fluoric	Sulphuric
Uranium	Copper	Phosphoric	Tartaric
Molybdena	Tin	Mucic	Succinic
Tungsten	Lead	Nitric	Phosphoric
Cobalt	Silver	Muriatic	Mucic
Antimony	Bismuth	Suberic	Nitric
Nickel	Antimony	Citric	Muriatic
Arsenic	Mercury	Tartaric	Suberic

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

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TABLES OF SIMPLE AFFINITY — *continued.*

Acids:
Fluoric
Arsenic
Lactic
Citric
Malic
Benzoic
Acetic
Boracic
Sulphurous
Nitrous
Carbonic
Prussic
Sulphur
Phosphorus
Water
Fixed oil

MAGNESIA.

Acids:
Oxalic
Phosphoric
Sulphuric
Fluoric
Arsenic
Mucic
Succinic
Nitric
Muriatic
Tartaric
Citric
Malic
Lactic
Benzoic
Ascetic
Boracic
Sulphurous
Nitrous
Carbonic
Prussic
Sulphur

ALUMINA.

Acids:
Sulphuric
Nitric
Muriatic
Oxalic
Arsenic
Fluoric
Tartaric
Succinic

Acids:
Mucic
Citric
Phosphoric
Lactic
Benzoic
Acetic
Boracic
Sulphurous
Nitrous
Carbonic
Prussic

SILEX.

Fluoric acid
Potash

OXIDE OF PLATINA.

OXIDE OF GOLD.*

Acids:
Gallic
Muriatic
Nitric
Sulphuric
Arsenic
Fluoric
Tartaric
Phosphoric
Oxalic
Citric
Acetic
Succinic
Prussic
Carbonic
Ammonia

OXIDE OF SILVER.

Acids:
Gallic
Muriatic
Oxalic
Sulphuric
Mucic
Phosphoric
Sulphurous
Nitric
Arsenic
Fluoric
Tartaric
Citric

Acids:
Lactic
Succinic
Acetic
Prussic
Carbonic
Ammonia

OXIDE OF MERCURY.

Acids;
Gallic
Muriatic
Oxalic
Succinic
Arsenic
Phosphoric
Sulphuric
Mucic
Tartaric
Citric
Malic
Sulphurous
Nitric
Fluoric
Acetic
Benzoic
Boracic
Prussic
Carbonic

OXIDE OF LEAD.

Acids;
Gallic
Sulphuric
Mucic
Oxalic
Arsenic
Tartaric
Phosphoric
Muriatic
Sulphurous
Suberic
Nitric
Fluoric
Citric
Malic
Succinic
Lactic
Acetic
Benzoic
Boracic

Acids:
Prussic
Carbonic
Fixed oils
Ammonia

OXIDE OF COPPER.

Acids;
Gallic
Oxalic
Tartaric
Muriatic
Sulphuric
Mucic
Nitric
Arsenic
Phosphoric
Succinic
Fluoric
Citric
Lactic
Acetic
Boracic
Prussic
Carbonic
Fixed alkalies
Ammonia
Fixed oils

OXIDE OF ARSENIC.

Acids;
Gallic
Muriatic
Oxalic
Sulphuric
Nitric
Tartaric
Phosphoric
Fluoric
Succinic
Citric
Acetic
Prussic
Fixed alkalies
Ammonia
Fixed oils
Water

OXIDE OF IRON.

Acids:
Gallic

* Omitting the oxalic, citric, succinic, and carbonic, and adding sulphureted hydrogen after ammonia.

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TABLES OF SIMPLE AFFINITY — *continued.*

Acids :
Oxalic
Tartaric
Camphoric
Sulphuric
Mucic
Muriatic
Nitric
Phosphoric
Arsenic
Fluoric
Succinic
Citric
Lactic
Acetic
Boracic
Prussic
Carbonic

OXIDE OF TIN.
Acids :
Gallic
Muriatic
Sulphuric
Oxalic
Tartaric
Arsenic
Phosphoric
Nitric
Succinic
Fluoric
Mucic
Citric
Lactic
Acetic
Boracic
Prussic
Ammonia

OXIDE OF ZINC.
Acids :
Gallic
Oxalic
Sulphuric
Muriatic
Mucic
Nitric

Acids :
Tartaric
Phosphoric
Citric
Succinic
Fluoric
Arsenic
Lactic
Acetic
Boracic
Prussic
Carbonic
Fixed alkalies
Ammonia

OXIDE OF ANTIMONY.
Acids :
Gallic
Muriatic
Benzoic
Oxalic
Sulphuric
Nitric
Tartaric
Mucic
Phosphoric
Citric
Succinic
Fluoric
Arsenic
Lactic
Acetic
Boracic
Prussic
Fixed alkalies
Ammonia

SULPHURIC ACID.
PRUSSIC. *
Barytes
Strontites
Potash
Soda
Lime
Magnesia
Ammonia

Glucine
Yttria
Alumina
Zircon
Metallic oxides

SULPHUROUS ACID.
SUCCINIC. †
Barytes
Lime
Potash
Soda
Strontites
Magnesia
Ammonia
Glucine
Alumina
Zircon
Metallic oxides

PHOSPHORIC ACID.
CARBONIC. ‡
Barytes
Strontites
Lime
Potash
Soda
Ammonia
Magnesia
Glucine
Alumina
Zircon
Metallic oxides
Silex

PHOSPHOROUS ACID.
Lime
Barytes
Strontites
Potash
Soda
Ammonia
Glucine
Alumina
Zircon
Metallic oxides

NITRIC ACID.
MURIATIC ACID. §
Barytes
Potash
Soda
Strontites
Lime
Magnesia
Ammonia
Glucine
Alumina
Zircon
Metallic oxides

FLUORIC ACID.
BORACIC ACID. ‖
ARSENIC ACID. ¶
TUNGSTIC ACID.
Lime
Barytes
Strontites
Magnesia
Potash
Soda
Ammonia
Glucine
Alumina
Zircon
Silex

ACETIC ACID.
LACTIC ACID.
SUBERIC ACID. **
Barytes
Potash
Soda
Strontites
Lime
Ammonia
Magnesia ††
Metallic oxides
Glucine
Alumina
Zircon

---

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

No. 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	1·194
Mercury	13·545	Acetic	1·168
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	Arsenious	3·7
Arsenic	8·310	Potash (hydrate)	1·7085
Sulphuret of arsenic (red)	3·225	Soda (do)	1·336
——— (yellow)	5·315	Ammonia liquid	0·760
Iron	7·788	Lime	2·3908
Sulphuret of iron	4·513	Magnesia	·346
Tin	7·299	Barytes	4·000
Zinc	6·861	Alumina	2·000
Manganese	6·850	Sulphate of potash	2·298
Antimony	6·712	——— soda	2·246
Sulphuret of antimony	4·368	——— magnesia	1·6603
Sodium	·935	Alum	1·719
Potassium	·85	Nitrate of potash	1·933
Phosphorus	1·714	Muriate of soda	2·120
Sulphur	1·990	——— ammonia	1·453
Charcoals	0.223 to 1·526	——— lime	1·76
Bitumens	0.892 to 1·337	Muriate of barytes	2·8257
SALINE SUBSTANCES.		Phosphate of soda	1·338
Sulphuric acid	1·855	Acetate of potash	2·1—?
Nitric acid	1·5	Tartrate of potash	1·5567

* Zircon after alumina.

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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 alöes	1·3586
Socotorine alöes	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
Gamboge	1·2216
Guaiacum	1·2289
Honey	1·45
Myrrh	1·3600
Olibanum	1·1732
Opium	1·3359
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	0·9433
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

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No. 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 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.

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

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No. 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* 4*th 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 *cubic inches* weigh	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 cubic 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.*
1 =	·00396
2 =	·00792
3 =	·01188
4 =	·01584
5 =	·01980
6 =	·02376
7 =	·02772
8 =	·03168
9 =	·03564

Drachm.	*Cubic Inch.*
1 =	·237618
2 =	·475236
3 =	·712854
4 =	·950472
5 =	1·188090
6 =	1·425708
7 =	1·663326

Ounce.	*Cubic Inch.*
1 =	1·900945
2 =	3·801890
3 =	5·702835
4 =	7·603780
5 =	9·504725
6 =	11·405670
7 =	13·306615
8 =	15·207560
9 =	17·108505
10 =	19·009450
11 =	20·910395

Pound.	*Cubic Inch.*
1 =	22·81134
2 =	45·62268
3 =	68·43402
4 =	91·24536
5 =	114·05670
6 =	136·86804
7 =	159·67938
8 =	182·49072
9 =	205·30206

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

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TABLE III.

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

Wine Pints.		*lbs. Troy.*		*lbs.*		*oz.*		*dr.*		*grs.*		*lbs. Avoirdup.*
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 Pounds.		*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. Avoird.		*lbs. Troy.*	*lbs. Avoird.*		*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. Avoirdup.*	*lbs. Troy.*		*lbs. Avoirdup.*
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			

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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

No. VI.

TABLE *showing 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.			*English.*			
			Miles.	*fur.*	*yds.*	*ft.*	*in.*
Millimetre	=	·03937						
Centimetre	=	·39371						
Decimetre	=	3·93710						
Metre	=	39·37100	= 0	0	1	0	3·37
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

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II. MEASURES OF CAPACITY.

		Cubic inches.		English. Tons.	hogs.	wine gal.	pints.
Millilitre	=	·06103					
Centilitre	=	·61028					
Decilitre	=	6·10280					2·1138
Litre	=	61·02800	=	0	0	0	5·1352
Decalitre	=	610·28000	=	0	0	2	
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.		Avoirdupois. lbs.	oz.	dr.
Milligramme	=	·0154				
Centigramme	=	·1544				
Decigramme	=	1·5444				
Gramme	=	15·4440				
Decagramme	=	154·4402	=	0	0	5·65
Hecatogramme	=	1544·4023	=	0	3	8·5
Kilogramme	=	15444·0234	=	2	3	5
Myriogramme	=	154440·2344	=	22	1	2

No. VII.

TABLES *showing the correspondence of English Weights and Measures with those of Holland, Sweden, and Germany.*

The English Ale Gallon contains 282 cubic inches; the Wine Gallon 231 cubic inches.

I. DUTCH.

1 lb. Dutch = 1 lb. 3 oz. 16 dwt. 7 grs. Troy.
787½ lbs. Dutch = 1038 lbs. Troy.

II. SWEDISH.

1 kanne of water Swedish = 48088·719444 grs. Troy, in weight; and 189·9413 English cubic inches.
1 lb. Swedish = 6556 grs. Troy.

III. GERMAN.

74 lbs. German Apothecaries' Weight = 74 lbs. Troy.
1 oz. Nuremberg medic. weight = 7 dr. 2 dwt. 9 grs. Troy.
1 mark Cologne = 7 oz. 2 dwt. 4 grs. Troy.

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