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

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

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

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

II. REPULSION.

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

a. CALORIC.

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

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

Philosophers are not completely agreed whether it is a property only of bodies, such as a vibration of their 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. It is radiated in the same manner as light, and in this state forms a part of the solar ray.[2] The rays are refrangible, and capable of reflection. It has no ascertainable gravity; and neither the addition nor the abstraction of it alters sensibly the weight of bodies.[3] It exists in two different states; in a free state, in which it is merely loosely mingled as it were, with other bodies; and, in a latent state, or one of intimate combination.

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

Sources of Caloric.

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

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

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

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

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

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

of gas, and combined with light and caloric, is decomposed during its union with the combustible, and its caloric and light are set free in a sensible form; while the oxygen itself remains combined with the combustible. The truth of this theory is generally supposed to be proved by the facts, that combustion does not go on unless oxygen be present: and it is more brilliant in oxygen gas than in common air. The products of combustion are always heavier than the body consumed; and this increase of weight is exactly equal to the quantity of oxygen which the air loses. Every combination of oxygen, however, with bodies does not produce the phænomena 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 made to ascertain the quantity of caloric evolved during the burning of different combustibles, and several experiments have been instituted by the most able chemists at different times for this purpose. The following table exhibits the quantity of caloric evolved by the combustion of different substances, the estimate being formed from the quantity of ice melted during the burning of one pound of each of the substances.[2]

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1 *Thomson's Chemistry*, 4th edit. i. 607.
2 *Thomson's Chemistry*, i. 610.

Substances burnt, 1 lb.	Oxygen consumed in lbs.	Ice melted in lbs.		
		Lavoisier.	Crawford.	Dalton.
Hydrogen	6	295	480	320
Carburetted hydrogen	4			85
Olefiant gas	3·5			88
Carbonic oxide	0·58			25
Oil	3·5	148	89	104
Wax	3·5	133	97	104
Tallow	3·5			104
Oil of turpentine				60
Alcohol				58
Æther	3·			62
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 becomes red-hot; and sparks are produced by the collision of hard bodies, particularly of flint with steel. This effect appears to arise from condensation, or forcing the integrant particles of the bodies closer together, so as to dislodge the latent caloric they contain, and give it out in the form of sensible caloric. The specific gravity of iron is increased ·052 by being hammered; and it becomes so hard and brittle that it cannot again be heated by percussion, until it has been exposed for some time to a red heat in the forge. By the collision of flint and steel the oxidizement of the steel is also effected, the sparks being small incandescent pieces of oxidized iron.

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

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

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

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

Distribution and Effects of free Caloric.

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

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

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

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

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

The thermometer commonly employed in this country is that of Fahrenheit[2]: but as three other thermometers are used on the continent, it may be proper to notice all of them, and point out the circumstances in which their scales differ.

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

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

[2] Fahrenheit was a German artist.

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

The scale of the thermometer of Celsius, which has been used in France since the revolution, begins at the freezing point of water, which is consequently marked 0, and the space between that and the boiling point is divided into 100 equal degrees; hence it has been named the *Centigrade Thermometer*. Each degree of this scale is $\frac{4}{5}$ths more than a degree of Fahrenheit's, or one of the latter is equal to $\frac{5}{9}$ths of a degree of the centigrade scale. To find, therefore, the degrees of Fahrenheit's scale, corresponding to those of the centrigade, 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 ths scale of Fahrenheit.

Reaumur's thermometer, which is still used in Italy and Spain, also commences at the freezing point, which is marked 0; and between this and the boiling point it is divided into 80 degree. Each degree is therefore $\frac{5}{4}$ths more than one of Fahrenheit's; and to reduce those of Reaumur to Fahrenheit's, the given number of the former must be multiplied by 9, and divided by 4, adding 32 to the quotient.[1]

[1] *TABLE showing the degrees of Reaumur's and Fahrenheit's thermometers corresponding with those of the centrigrade thermometer.*

Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.
100	80·	212·	68	54·4	154·4	36	28·8	96·8	5	4·	41.
99	79·2	210·2	67	53·6	152·6	35	28·	95·	4	3·2	39·2
98	78·4	208·4	66	52·8	150·8	34	27·2	93·2	3	2·4	37·4
97	77·6	206·6	65	52·	149·	33	26·4	91·4	2	1·6	35·6
96	76·8	204·8	64	51·2	147·2	32	25·6	89·6	1	0·8	33·8
95	76·	203·	63.	50·4	145·4	31	24·8	87·8	0	0·	32·
94	75·2	201·2	62	49·6	143·6	30	24·	86·	1	0·8	30·2
93	74·4	199·4	61	48·8	141·8	29	23·2	84·2	2	1·6	28·4
92	73·6	197·6	60	48.	140·	28	22·4	82·4	3	2·4	26·6
91	72·8	195·8	59	47·2	138·2	27	21·6	80·6	4	3·2	24·8
90	72·	194·	58	46·4	136·4	26	20·8	78·8	5	4·	23·
89	71·2	192·2	57	45·6	134·6	25	20·	77·	6	4·8	21·2
88	70·4	190·4	56	44·8	132·8	24	19·2	75.2	7	5·6	19·4
87	69·6	188·6	55	44.	131·	23	18·4	73·4	8	6·4	17·6
86	68·8	186·8	54	43·2	129·2	22	17.6	71·6	9	7·2	15·8
85	68·	185·	53	42·4	127·4	21	16·8	69·8	10	8·	14·
84	67·2	183·2	52	41·6	125·6	20	16.	68·	11	8·8	12·2
83	66·4	181·4	51	40·8	123·8	19	15·2	66·2	12	9·6	10·4
82	65·6	179·6	50	40·	122·	18	14·4	64·4	13	10·4	8·6
81	64·8	177·8	49	39·2	120·2	17	13·6	62·6	14	11·2	6·8
80	64·	176·	48	38·4	118·4	16	12·8	60·8	15	12·	5·
79	63·2	174·2	47	37·6	116·6	15	12·	59·	16	12·8	3·2
78	62·4	172·4	46	36·8	114·8	14	11·2	57·2	17	13·6	1·4
77	61·6	170·6	45	36·	113·	13	10·4	55·4	18	14·4	0·4
76	60·8	168·8	44	35·2	111·2	12	9·6	53·6	19	15·2	2·2
75	60·	167·	43	34·4	109·4	11	8·8	51·8	20	16·	4·
74	59·2	165·2	42	33·6	107·6	10	8·	50·	21	16·8	5·8
73	58·4	163·4	41	32·8	105·8	9	7·2	48·2	22	17·6	7·6
72	57·6	161·6	40	32·	104·	8	6·4	46·4	23	18·4	9·4
71	56·8	159·8	39	31·2	102·2	7	5·6	44·6	24	19·2	11·2
70	56·	158·	38	30·4	100·4	6	4.8	42·8	25	20·	13·
69	55·2	156·2	37	29·6	98·6						

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

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

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

Reau.	Cent.	Fahr.	Reau.	Cent.	Fahr.	Reau.	Cent.	Fahr.
80	100·	212·	46	57·5	135·5	12	15·	59·
79	98.75	209·75	45	56·25	133·25	11	13·75	56·75
78	97·5	207·5	44	55·	131·	10	12·5	54·5
77	96·25	205·25	43	53·75	128·75	9	11·25	52·25
76	95·	203·	42	52·5	126·5	8	10·	50·
75	93·75	200·75	41	51·25	124·25	7	8 75	47·75
74	92·5	198·5	40	50·	122·	6	7·5	45·5
73	91·25	196·25	39	48·75	119·75	5	6·25	43·25
72	90·	194·	38	47·5	117·5	4	5·	41·
71	88·75	191·75	37	46·25	115.25	3	3·75	38·75
70	87·5	189·5	36	45·	113·	2	2·5	36·5
69	86·25	187·25	35	43·75	110·75	1	1·25	34·25
68	85·	185·	34	42·5	108·5	0	o	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			

instance, being sufficient, by increased expansion, to raise it 94 in the second.[1]

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

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

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

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

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

Mercury.	Water.	Water saturated with salt.	Sulphuric acid.	Muriatic acid.	Oil of turpentine.	Ether.	Fixed Oils.	Alcohol.	Nitric acid.
·0200 = $\frac{1}{50}$	·0466 = $\frac{1}{21.5}$	·0500 = $\frac{1}{20}$	·0600 = $\frac{1}{17}$	·0600 = $\frac{1}{17}$	·0700 = $\frac{1}{14}$	·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° it expands it.

All gaseous bodies suffer the same expansion by the same additions of caloric, supposing the circumstances to be equal. Their expansion is almost perfectly equable, or the same augmentation takes place by the same addition of caloric at every degree of temperature between the freezing and the boiling point of Fahrenheit's thermometer. By the experiments of Gay Lussac, 100 parts of atmospheric air, heated from 32° to 212° expand 137·5 parts, or $\frac{1}{480}$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 each other to such a distance as to render them easily moveable on one another in every direction. All solids, with a very few exceptions, are susceptible of the fluid form, when exposed to a suf-

ficient degree of heat; and all liquids, with the exception of alcohol, become solid when exposed to very low temperatures. The particular temperatures necessary for the production of these changes, however, are exceedingly various, but for the same bodies they are always the same.[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 to water is an example of the first; the melting of glass, of wax, and other unctuous matters, is an instance of the second. There are some bodies, nevertheless, which cannot be melted or *fused*, owing to their suffering chemical decomposition at a lower temperature than is required for their *fusion*:—a piece of wood, for instance, cannot be melted by any application of heat.

Although the melting point, in most cases, is always the same in the same bodies, yet circumstances may vary it; and the admixture of other substances may alter it very considerably. Thus, the melting point of ice, or, what is the same thing, the freezing point of water, is 32°; but, by exposing water slowly to the action of freezing mixtures, it may be cooled down to 22° before it freezes. The addition of salt renders this point still lower, as may be seen by the following Table.[2]

Names of salts.	Proportion by weight dissolved in 100 parts of water.	Freezing point.
Common salt.....	25·	4·
Sal ammoniac.....	20·	8·
Rochelle salt.....	50·	21·
Sulphate of magnesia	41·6	25·5
Nitre.....	12·5	26·
Sulphate of iron	41·6	28·
——— of zinc.....	33·3	28·6

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The degree of temperature at which all bodies capable of ignition begin to be ignited, or become red hot, is nearly the same,—about the 800th degree of Fahrenheit; and by raising the temperature the illumination increases, until a perfectly white light is produced, which is the highest point of ignition. Ignition is supposed to arise from the extrication of the light, which is regarded as a constituent of the ignited body, by the repulsive agency of the additional caloric; but this explanation of the phænomenon is liable to some objections, and the real cause remains still undetermined. As a pharmaceutical agent, *caloric* is of the first importance, in the majority of cases producing decomposition; but in others favouring combination. The decomposition most easily effected by it is the separation of the more volatile from the more fixed ingredients of compounds. Thus in the process of distillation (see *Operations*), when weak spirits are heated, the alcohol separates from the water, owing to its superior volatility, and by condensation is obtained as a distinct substance. Almost all compounds into which oxygen has entered without having occasioned combustion, as nitric acid, hyperoxymuriatic acid, and some metallic oxides, suffer likewise decomposition by caloric. All compound bodies containing combustibles are also decomposable by it; as are also compounds consisting of two or more combustible ingredients, in combination with oxygen, as almost all animal and vegetable matters. On the contrary, the compounds which are little or not at all affected by caloric, as far as regards the composition, are those which have been formed by combustion; such as water, phosphoric acid, and carbonic acid.[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 subtle particles which are constantly emanating in straight lines from luminous bodies. The size of these is too minute to be appreciated; but their velocity is estimated to be at the rate of 200,000 miles in a second. They appear to repel each other like those of caloric.

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

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

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

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

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

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

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

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

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

Light has a powerful tendency to decompose liquid oxy-muriatic acid; and also nitric acid, which it renders red and fuming, even when it is contained in vessels accurately closed. Almost all the vegetable and animal colouring matters have their brilliancy and colour much impaired by long exposure to the sun's rays: they affect also the colour and the properties of vegetable powders kept in clear glass bottles. Light even seems to have a strong influence on the process of crystallization; for, if light be only partially admitted to a crystallizing solution, the crystals will be larger and more numerous on the enlightened side; and often the whole mass will radiate towards this point. 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 phænomena of electrity depend on a very subtile fluid, which is a powerful chemical agent, capable of producing im-

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

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

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

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

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

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

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

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

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

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

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

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

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

SECTION II.[1]

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

I. SOLIDS.

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

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