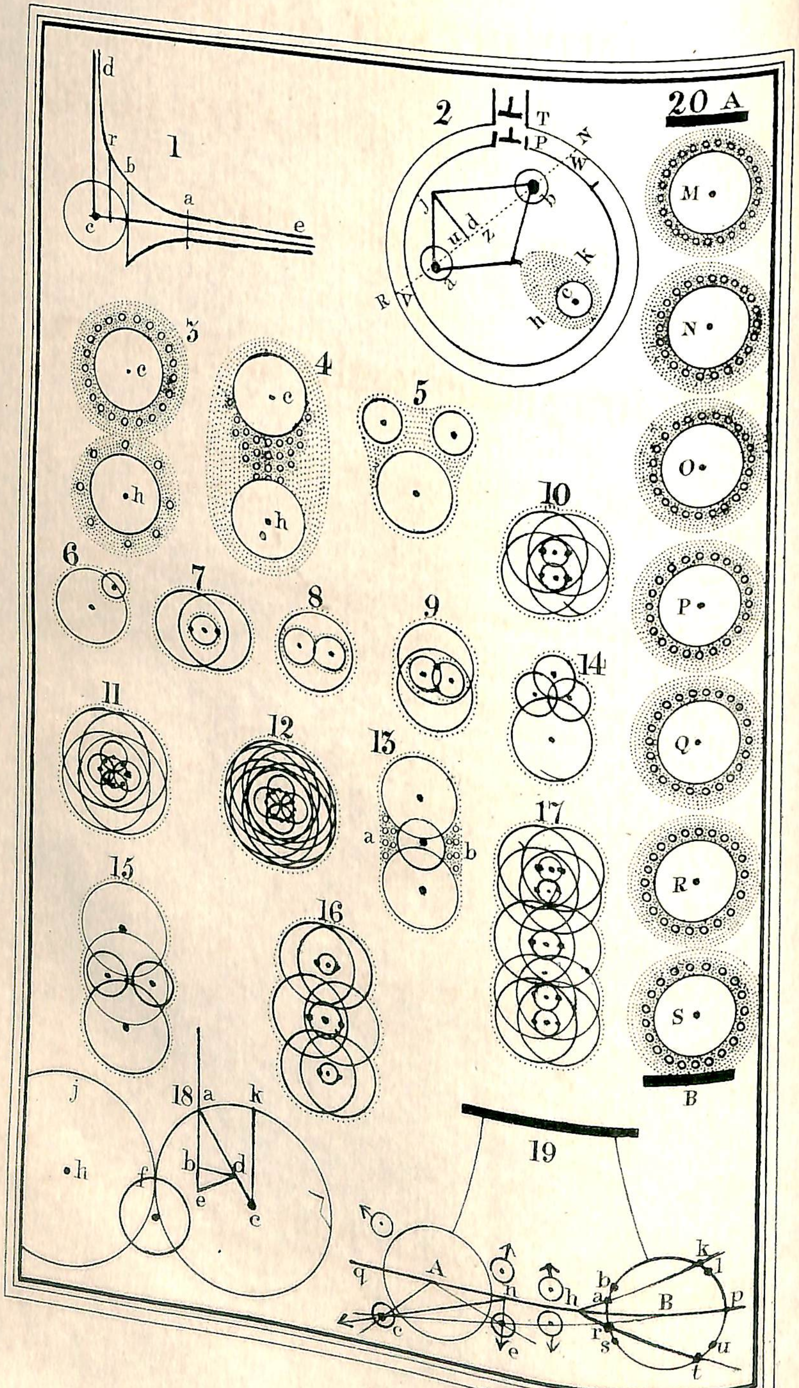

IMPORTANT FACTS,

DERIVED MATHEMATICALLY,

FROM A GENERAL THEORY,

Embracing many results in Chemistry,

WHICH ARE DENOMINATED ULTIMATE FACTS.

BEING A PAPER, PART OF WHICH WAS COMMUNICATED TO THE BRITISH ASSOCIATION, AUGUST 23, 1836; AND TO WHICH ARE ADDED SEVERAL IMPORTANT PROPOSITIONS ON EVAPORATION, WITH AN APPENDIX, SHEWING THE GENERAL APPLICATION OF THE THEORY TO ELECTRICITY AND MAGNETISM:

WITH SOME OBSERVATIONS ON THE ORIGIN,
FORMATION, NATURE, AND USE OF COMETS.

BY THOMAS EXLEY, A. M.

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1837.

TO THOMAS THOMSON, M.D.

F.R.S., L. & E., F.L.S., F.G.S., &c.

REGIUS PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF GLASGOW.

Sir,

Being persuaded that no man has more extensively, deeply, and critically examined the various Philosophical Theories, which have relation to Chemistry than yourself, I have the greatest satisfaction in committing these labours to your patronage; and having requested your permission, nothing could be more satisfactory to me than the reply, in which you were pleased to say; "I am persuaded that your doctrine will place the "foundation of Chemistry, upon a rock as firm and lasting as "the doctrine of Gravitation itself." This Sir, from you, who have investigated every part of Chemical Theory, has conferred on me a degree of honor, which calls for my warmest acknowledgments.

May your health and vigour long continue, that you may pursue and extend those researches, which have already rendered you immortal in the scientific world.

THOMAS EXLEY.

Bristol, February, 1837.

IMPORTANT FACTS, &c.

(Part of which was communicated to the Chemical Section of the British Association, August 23rd, 1836.)

The object of this paper is to place Chemistry under the domain of mathematical science, and to establish the New Theory of Physics on the basis of easy calculations, and mathematical proofs.

The two principles which form the foundation are these; viz.

1st. Every atom of matter consists of an indefinitely extended sphere of force, which varies inversely as the square of the distance from the centre; and that this force acts *towards* the centre, and is called attraction, at all distances, except in a small concentric sphere, in which it acts *from* the centre, and is there called repulsion.

2nd. That there is a difference in atoms, arising from a difference in their absolute forces, or in the radii of their spheres of repulsion, or in both these respects.

The theories of Newton and Boscovich agree perfectly with this, as far as regards the attraction in the first principle: after which both these philosophers conceive a series of alternate spheres of attraction and repulsion, governed by unknown laws, but as regards the change, the forces graduate the one into the other. Boscovich terminates with a sphere of repulsion varying inversely as the simple distance; which makes the force at the centre infinite; but Newton closes with a minute solid, which is an infinite force at some finite distance from the centre. The new theory rejects all these hypothetical unsubstantiated forces, and their feigned alternations; admitting of but one sphere of repulsion, in which, without interruption, the law of gravitation of the attractive sphere, is invariably continued down to the centre, where it consequently terminates in a force infinitely greater even than that of Boscovich. The change of direction of the force takes place *per saltum* at the surface of the sphere of repulsion: and why not? there is no reason to prevent such a change, and had it been otherwise, the law of continuity of the force itself would have been broken, and heterogeneous forces would have been introduced; but here the law is continued, which is a matter of great importance; since it preserves a perfect harmony of nature, in the great spaces of the universe, and in the minute spaces in which chemistry, and its connate sciences, produce all their phenomena.

The inductive philosophy requires, and demands this continuity in the law of gravitation: and, unless the contrary could be shown in any instance, we have as much right to say, that this law does not exist in the infinity of places where no observations have been made, as to say it does not exist in the sphere of repulsion; especially since we know there is a central repulsion, and not a single instance of repulsion according to any other law can be proved to exist, as belonging to atoms of matter. Thus by induction the first principle is established, and must rest on the same foundation as the attractive force of gravity, unless some phenomenon can be found which proves the contrary.

The ordinates of the curve *e a b d*, fig. 1. may represent the force as to quantity, proceeding to an infinitely small force towards *e*, and an infinitely great one towards *d*, when the ordinates fall within the circle at *c*, whose circumference shows the extent of the sphere of repulsion, the force is repulsive, when they fall without that circle, it is attractive, the direction changes at *b*; if we wish to represent direction as well as quantity by the curve, the branch *b a e* must lie on the other side of the axis, as shown in the figure.

The second principle is perfectly simple and natural, and is also established by induction from phenomena and the first principle: for we know there is a difference in atoms, and this together with the first principle, renders the second a necessary consequence.

The accordance of this theory with facts has been shown in my treatises on Physics, and Optics; it now remains, in order to confirm the validity of the principles, to derive from them mathematically, the results, which have been established by experiment as ultimate facts.

It will be of course admitted, that the Creator originally caused to exist a just and adequate number of atoms of every requisite sort, for the purposes of his grand design in the structure of the universe. All things were ordered with the utmost precision, according to number, weight, and measure; nothing in excess, nothing in defect.

Every variety of atoms may be assumed, but to find what sorts really exist, phenomena should direct the assumptions.

In my "New Theory of Physics," it was stated, that nature presents *two classes* of atoms; the one comprehending the elementary substances most generally known; as oxygen, hydrogen, carbon, &c. which adhering with great tenacity, may be termed, *tenacious atoms;* (till a better name be found). The other included such matter or atoms as manifest their existence by motions, and actions, under a form, which has been denominated ethereal, and hence may be called *ethereal atoms:* to this class was assigned, the electric fluid, caloric, and light.

In the same work the atoms of the electric fluid were considered as having a much greater absolute force, than those of caloric or light.

This has been abundantly confirmed by subsequent observations, entitling electric atoms to the rank of an intermediate class. Hence we have three classes of atoms, viz. tenacious, electric, and ethereal atoms. Of the first and third classes are many sorts, but probably only one sort of electric atoms: this division and arrangement will at any rate be fully sufficient for our present purpose.

The distinction of classes is founded in a *very great*, that of the sorts, in a moderate difference of the absolute forces; thus an electric atom may be several hundred, or perhaps thousand times less than that of the weakest tenacious atom, and yet several millions of times greater than that of an ethereal atom. It may be noticed here, that the atomic weight of hydrogen is assumed 1, and on this scale 16 is taken for that of oxygen. It appears to me exceedingly unfortunate, that the British chemists have adopted 8, instead of 16. They tell us, which shows a want of confidence in their own arguments, that it is of no great consequence, which of these opinions be adopted. This is true, as it regards many experimental determinations, but in theory, it is exceedingly important. Is it of no consequence to know, whether a compound contain in each particle, 2, 3, 4, &c. atoms? If oxygen be 8, a particle of ether contains 10 atoms, but if oxygen be 16, it contains 15 atoms: would not such a difference alter all, or most of its properties? is it of no consequence, when we know that chemical combinations produce great changes of properties? A question so deeply scientific ought not to be treated with indifference.

In favour of 8, it has been said, First, that the combination of one atom of A, with one of B, is stronger than with two of B; because the latter is weakened by the mutual repulsion of B and B. But it may as well be said, the combination is strengthened by the attraction of B and B; for like as well as unlike atoms attract each other: nor will alternate spheres of attraction and repulsion assist the argument; for B may as well be in the one as the other.

2nd. It is said that such compounds as are with most difficulty decomposed, must in general be presumed to be binary: but for this we have no good reason, the contrary is often true, and perhaps it is true in a great majority of cases.

3rd. It is argued, that in chemical compounds, the most simple are universally the most difficult to decompose: but this cannot be proved, if by most simple we are to understand the order of binary, ternary, &c. Doubtless that compound, which is most generally formed, and constantly maintained in nature, whether binary or ternary, is the most difficult to decompose.

4th. The analogies which have been adduced, in favour of this side of the argument, are generally far fetched, or inapplicable; and some of them, with greater force, may be brought to corroborate the opposite opinion.

In favour of 16, as the atomic weight of oxygen, we may observe, 1st, that the other simple gases, hydrogen, nitrogen, and chlorine, contain the same number of atoms in equal volumes; and oxygen appears, as much as any of them, to be a simple element; and therefore ought not to be made an exception without very evident reason.

Second. Analogy establishes this view, out of a multitude of striking examples; take the four following compounds, in which the analogies are so strong, that in respect of their composition, what is said of the one, may be said of the other, by simply changing the terms.

1. Sulphurous acid is the the sole gaseous product, when sulphur is burnt in dry oxygen gas, and the resulting volume is the same as that of the oxygen consumed.

2. Carbonic acid is the sole gaseous product, when carbon is burnt in oxygen gas, and the resulting volume is the same as that of the oxygen consumed.

3. Steam is the sole gaseous product, when oxygen is burnt in hydrogen gas, and the resulting volume is the same as that of the hydrogen consumed.

4. Sulphuretted hydrogen is the sole gaseous product, when sulphur is burnt in hydrogen gas, and the resulting volume is the same as that of the hydrogen consumed.

And besides, all these substances have been obtained in the form of gases, and limpid liquids: now these striking analogies prove that they are formed after the same manner from their elements; but all parties agree that the two first compounds contain three atoms each: hence, we must conclude that the two others are ternary compounds; from which it follows that 16 is the atomic weight of oxygen.

As another example, take sulphurous and hyposulphurous acids; and also water and deutoxide of hydrogen. Then 1st. Sulphurous acid is formed by burning sulphur in oxygen gas, and the volume of oxygen is not changed; it may be passed through red hot tubes, without decomposition: but several substances which have a strong affinity for oxygen, as potassium, carbon, &c. decompose it, and by slight pressure it becomes a limpid liquid. Hydrosulphurous acid contains twice as much sulphur as sulphurous acid; it is easily decomposed, and cannot remain permanent at common temperatures.

Making the proper changes for the terms, we may read, the same sentence for the analogous substances. Thus, 2nd:—

Water is formed by burning oxygen in hydrogen gas, and the volume of hydrogen is not changed; it may be passed through red hot tubes, without decomposition; but several substances which have a strong affinity for oxygen, as potassium, carbon, &c. decompose it, and at common temperatures, it is a limpid liquid. Deutoxide of hydrogen contains twice as much oyxgen as water does; it is easily decomposed, and cannot remain permanent at common temperatures.

Now sulphurous acid is allowed on all hands to be two atoms oxygen, and one sulphur, and hyposulphurous acid, one of each element; therefore, one of water is two atoms hydrogen, and one oxygen, and deutoxide of hydrogen is one of each element: therefore 16 is the atomic weight of oxygen.

The same may be shown from many instances; one in addition will be sufficient.

1. A volume of carbonic oxide is double that of its oxygen, and combined with another equal volume of oxygen, it becomes carbonic acid, without change of volume.

2. A volume of nitric oxide is double that of its nitrogen, and combined with another equal volume of nitrogen, it becomes nitrous oxide, without change of volume.

Analogy therefore shows, that these are composed after the same manner: now it is universally allowed, that carbonic oxide is one atom oxygen, and one carbon; hence nitric oxide is one nitrogen, and

one oxygen, but by weight they are as 14 to 16, and 14 is the weight of an atom of nitrogen; therefore, 16 is the atomic weight of oxygen.

In these arguments I have made no use of my own Theory, which, if applied, would prove directly that 16 is the right number for oxygen.

The other atomic weights, used in this paper, are taken from Dr. Thomson's determinations, doubling some of them on account of taking 16 for oxygen. They are inserted in the following table, with the numbers of Berzelius annexed; the substances in italics have double the numbers given by Dr. Thomson.

Name.	Atomic Thomson.	Weight by Berzelius.	Name.	Atomic Thomson.	Weight by Berzelius
Oxygen,	16	16·026	Arsenic,	38	75·329
Sulphur,	32	32·239	*Boron*,	16	21·793
Nitrogen,	14	14·189	*Carbon*,	12	12·250
Fluorine,	18		*Tellurium*,	64	129·243
Chlorine,	36	35·470	*Titanium*,	52	62·356
Bromine,	80	79·263	*Silicon*,	16	44·469
Iodine,	126	123·205	Hydrogen,	1	1
Selenium	80		Mercury,	100	202·868
Phosphorus,	16	31·436	*Tin*,	116	117·839

Berzelius has with great propriety, set down the results of his very accurate experiments, without correcting them by theory; it would be well to give also, the results thus corrected. From the calculated and experimental specific gravities of 68 compounds in the table appended to the 17th proposition, it appears to me, that the numbers, as given by Dr. Thomson, are nearer the truth than those given by Berzelius: and this more particularly seems to be the case in respect to two or three, which I have examined more at large, which may be seen as to carbon, from the compounds in the following table. The specific gravities are calculated by a rule shown at the 17th proposition.

In these ten substances, if $12\frac{1}{4}$ be taken for the atomic weight of carbon, the calculated specific gravity exceeds that found by experiment. In three of them, it is so even when 12 is taken, and in the rest, the defect is very much less than the excess, except in naphthaline; which shows that 12 is much nearer the true atomic weight of carbon than $12\frac{1}{4}$. Several other examples may be taken from the enlarged table appended to proposition 17, which show the same with equal evidence.

Name.	Atomic wt. of carbon.	Specific By calculation.	Gravity By experiment	Authority and result.
Carbonic oxide	12	·9721	·9732	Thenard & Berzelius, mean; 1st ·0011 defect, 2nd ·0163 excess.
	$12\frac{1}{4}$	·9895		
Carbonic acid -	12	1·5277	1·5213	Thenard & Gay Lussac, mean; 1st ·0064 excess, 2nd ·0035 excess.
	$12\frac{1}{4}$	1·5451		
Light carburetted hydrogen	12	·5555	·5590	Thomson; 1st ·0035 defect, 2nd ·0138 excess.
	$12\frac{1}{4}$	·5728		
Alcohol . .	12	1·5972	1·6133	Gay Lussac; 1st ·0161 defect, 2nd ·0186 excess.
	$12\frac{1}{4}$	1·6319		
Etherine .	12	1·9444	1·9100	Faraday; 1st ·0344 excess, 2nd ·0691 excess.
	$12\frac{1}{4}$	1·9791		
Ether . .	12	2·5694	2·5830	Gay Lussac & Depretz, mean; 1st 0136 defect, 2nd ·0558 excess.
	$12\frac{1}{4}$	2·6388		
Naphtha .	12	2·8472	2·8330	Saussure; 1st ·0142 excess, ·0663 excess.
	$12\frac{1}{4}$	2·8993		
Naphthaline	12	4·4444	4·5280	Dumas; 1st ·0836 defect, 2nd ·0032 excess.
	$12\frac{1}{4}$	4·5312		
Paranaphthal.	12	6·6666	6·7410	Dumas; 1st ·0074 defect, 2nd ·1860 excess.
	$12\frac{1}{4}$	6·9270		
Camphene .	12	4·7222	4·7670	Dumas, 1st ·0348 defect, 2nd ·0420 excess.
	$12\frac{1}{4}$	4·8090		

PROPOSITION 1. *To investigate the conditions of a collection of atoms of the same kind in space, situated in such positions, as they would take by their mutual actions.*

1. It is hardly necessary to observe, that they would form a sphere, whose centre would be the centre of gravity of the mass: for if the mass were not spherical, the more elevated atoms would not be supported in a stable equilibrium.

2. Let R T N, fig. 2, represent this sphere, *s* its centre; then all the lower strata of atoms, that is those nearest the centre, are pressed by the upper; hence the lower contiguous atoms will be pressed so, that their centres may be within each other's repulsion, they will therefore repel each other by forces inversely as the squares of their distance; and this distance and the pressure will depend on the radius of the sphere, and situation of the atoms.

3. If any concentric sphere be taken within the former, as V P W; then, the pressure on the spherical surface V P W depends on the gravity of the exterior shell, towards the inner sphere, which acts as if its atoms were collected in the centre; and this pressure may be equal to any given amount, since the thickness of the shell may be augmented by a continual accession of atoms.

4. If the inner sphere be small in comparison of the whole, the density of its separate parts will be nearly the same.

5. Instead of the pressure of the exterior shell, any equivalent pressure on the surface V P W may be substituted; as that, for instance, represented by a force on th piston P, of the vessel V P W.

6. The number of atoms in the sphere depends on its magnitude, and not on the absolute force of the atoms, or on their spheres of repulsion, if these are taken within certain limits. For if the absolute force be altered in any ratio, then both the pressures of the several atoms towards each other, and the repulsions of contiguous atoms are altered in the same ratio; and therefore the same equilibrium will remain. Also, when the spheres of repulsion are altered, the same pressures will still bring the contiguous atoms to the same distances from each other, provided they are not extended to more distant atoms, or diminished more than to the distance between contiguous atoms.

The same may be thus shown; let a = the absolute force of each atom, r the radius of the sphere, b, = the vertical distance between the highest atom, and the first below it, c = the distance to the 2nd below it, &c. proceeding to the limit of the sphere of repulsion, n the number of atoms in the sphere. Then the force pressing the highest atom downward is $\frac{2an}{r^2}$; since the force is the same as if the atoms of the sphere were in the centre, (Newt. Prin. b. 1. p. 76,): again, the resistance to the descent of this atom is $2a\left(\frac{1}{b^2}+\frac{1}{c^2}+\dots\right)$: now these forces are equal, since they are opposite, and in equilibrium: therefore, $n = r^2\left(\frac{1}{b^2}+\frac{1}{c^2}+\dots\right)$, which is independent of a, and also of any variation in the sphere of repulsion, within the limits of the two last terms of the series, so that there will be the same number of atoms in the vertical line: if the sphere of repulsion were varied to exceed the greatest of those limits, the distance would increase, or if to be less than the less of those limits, it would contract.

7. By the first principle the sphere of repulsion is indefinitely small, and if it do not extend further than the second atom in the vertical line, we shall have $nb^2 = r$ or $b = \frac{r}{\sqrt{n}}$: that is the distance between the two upper strata is equal to the radius of the sphere divided by the square root of the number of atoms it contains. And this will remain the same, however the sphere of repulsion is varied, so that it is not less than $\frac{r}{\sqrt{n}}$, nor greater than the distance between the 1st, and 3rd strata.

8. If the spheres of repulsion do not extend farther than to the centres of the atoms, next beyond the contiguous ones, the repulsion between two atoms is inversely as the square of their distance; and hence (Newt. Prin. b. 2. p. 23. Sch.) the compressing force, in any part of the sphere will be as the 4th power of the cube root of the density.

PROPOSITION 2. *To investigate the general effects, when tenacious atoms are placed in a sphere of ethereal matter.*

Let s, (fig. 2,) be the centre of the spherical mass, R T N a concentric spherical vessel, confining the enclosed mass under the same pressure as before, so that the exterior part being removed, there would still be the same equilibrium within: the pressure on a given part of the surface may be represented by the force required to sustain the piston T, at that surface. Let P V W be another concentric vessel, confining tenacious atoms, but admitting a perfectly free communication of ethereal atoms.

1. Let *c* be a tenacious atom in the inner vessel, then the action of the shell, exterior to the distance *s c*, does not disturb the atom *c*, or the ethereal atoms nearer the centre, (Newt. Prin. b. 1. p. 70), but the mutual actions of the inner part solicit *c* towards the centre, by a force proportional to its distance; now, suppose *c* retained by some means in its place: it will attract to its surface an atmospherule of ethereal matter: for if we suppose its attraction not to act, the ethereal matter will be uniformly distributed, quite to the surface of repulsion, just as if *c* had been absent; again, let the attraction act, and it is manifest, that a portion of the surrounding medium will be attracted towards its surface, and because of the given pressure at T, and the perfectly free communication of ethereal matter, between the vessels, the equilibrium will be speedily restored: the most dense part of the atmospherule will be on the line *c s*, on the side towards *s*: for since the mutual actions of the atoms, within the distance *s c*, tend to urge *c* towards the centre *s*, so they themselves will be urged towards the space between *s* and *c* to produce an equilibrium. In this state the supposed retaining force may be removed from *c*, and the equilibrium will remain, for *c* now presses, and is pressed, equally on all sides: but this equilibrium is not stable, because the atmospherule is most dense between *c* and *s*; hence, if the mass be affected with a disturbing force, so as to move *c* out of the line *c s*, it will begin to move towards *s*, and this effect will be greater, the further *c* is from *s*. When *c* is at *s*, its atmospherule will be spherical.

2. Because the force of the most powerful atom, even at small given distances from the centre, is extremely small, the atmospherule will be inappreciable at all moderate distances from the surface of repulsion; and very near that surface it will be the more dense, and more extensive, as the absolute force is greater, and as the sphere of repulsion is less: hence the effect of a tenacious atom, in respect to its atmospherule, need not be considered as extending to more than a very small distance.

3. Next, let there be two tenacious atoms in the inner vessel, *a* and *b*, near each other, and let their forces on an ethereal atom at *g*, be resolved into two, one in R N, passing through the centres *a* and *b*, and the other *g d*, perpendicular to R N. When *d* is between *a* and *b*, the forces in R N oppose each other, and act by their difference, but in other cases they conspire, and act by their sum: the forces in *g d* always conspire, and act by their sum, and since these forces are equal on every side of the line R N, their constant effect is to condense ethereal matter on that line; and this applies with the most appreciable effect between *a* and *b*, when these atoms are near each other. Hence there will be an atom, as *z*, in *a b* undisturbed, in the middle when *a* and *b* are equal, but in other cases nearer to the more powerful atom.

4. When there are several tenacious atoms in the inner vessel, each will be surrounded with an atmospherule extending to a minute distance from the surface of repulsion, and the atmospherules will be most dense in the line joining two contiguous atoms.

5. If there are several sorts of ethereal matter in the inner vessel, those which have the greatest absolute force, and least sphere of repulsion, will form the lower strata of the atmospherules, and fall most between the two atoms; because when the equilibrium is disturbed, such atoms are most easily moved among the rest, by the actions of the tenacious atoms, as will easily be seen. For the same reasons, if electric atoms are present, they will be collected in the lowest strata, and in the line joining the atoms, along with their own small atmospherules.

6. It is also manifest, that the atmospherules, both of the tenacious and electric atoms, will be more dense, when they are situated in a more dense body of ethereal matter.

7. When there is a large collection of tenacious atoms in the inner vessel, the situations they would naturally assume, would be such as to form a sphere concentric with the vessel, as is manifest from the above reasoning. If the radius of this sphere be less than that of the vessel, there will be no additional pressure on its surface V P W; which is evident, since the same density of the ethereal matter remains at that surface. But when the radius of the sphere of tenacious atoms becomes equal to that of the vessel, if more be introduced, there will be pressure on that surface, increasing as the number of tenacious atoms is augmented; and this pressure on a given part of the surface may be represented by a force on the piston P sustaining the force thus pressing at that surface.

8. If from the centre of the vessel there issue a great attractive force, varying according to the same law, it will manifestly tend to condense both the tenacious and the ethereal atoms.

9. The common terrestrial atmosphere of tenacious atoms is a spherical shell of such matter, and that of the ethereal matter is a far more extensive shell of ethereal atoms, both condensed by the force of terrestrial gravity, which may be considered as a great force emanating from the centre of gravity of the earth.

Scholium. Observation shows that the terrestrial atmosphere of common matter extends to about 40 or 50 miles, and it may be reasonably inferred, that the terrestrial atmosphere of ethereal matter extends several hundreds of miles.

Proposition. 3. *Things being as in the last proposition, the spheres of repulsion of the tenacious atoms, will intersect each other, or be kept apart by intervening ethereal matter, according to the pressures at T and P, and the absolute force and spheres of repulsion of the tenacious atoms.*

First, suppose the tenacious atoms retained in their places by some means, contiguous atoms being so near each other that their atmospherules are in contact or nearly so; now the forces tending to bring them nearer, are the pressure at P, and their own attraction towards each other; and the forces tending to separate them are the pressure at T, and their atmospherules, which, (prop 2, case 4,) will be most dense between them. Now if the pressure at T be increased, and consequently the atmospherules between them, (prop. 2, case 6,) the separating force is increased, while the rest remains; hence, by increasing the pressure at T, sufficiently, when the retaining force is removed, the tenacious atoms would recede. On the other hand, when the pressure at T remains, but that at P increases, the tenacious atoms will be forced nearer together, and if this be increased till their spheres of repulsion intersect, then the ethereal matter, within the common parts of the spheres of repulsion, will be repelled from the line joining the centres, as may be shown by resolving the forces as in proposition 2, case 3; hence when this happens the atoms will, by the pressure and their attraction increased by their proximity, rush together. If the absolute forces be varied, and even the spheres of repulsion within certain limits, the same equilibrium will remain, if the whole body be undisturbed by foreign agency; but if any displacement from external action occur, the tenacious atoms will approach, and the more readily as their absolute forces are greater, or spheres of repulsion less; for reasons such as shown prop. 2. case 5th. Hence the tenacious atoms will be kept apart by intervening ethereal matter or not, as stated in the proposition.

Cor. 1. When the tenacious atoms are kept apart by intervening ethereal matter, the mass will form a body similar to that of a gas, and may be called a gaseous body: in other cases the mass will have the form of a liquid or a solid.

Cor. 2. In a given gaseous body, the pressure at P varies as the pressure at T, when the volume is given.

For in this case, the pressure at P is the sole cause of diminishing, and that at T of increasing the volume, and since the volume is given, the Cor. is manifest.

Proposition 4. *Things being as in the last proposition, and the tenacious atoms in the inner vessel kept apart by intervening ethereal and electric atoms; if the pressure at T be given, and that at P varied; the density of the mass of tenacious atoms will vary as the compressing force.* (1)

Let the increment of density, produced by a given increment of compressing force, be divided into equal parts, and the increment of pressure into the same number of parts, such that taken in order, each shall produce one of the equal parts of the increment of density, and let the number of these parts be increased, and consequently their magnitude diminished without limit; then taking u to represent the compressing force, and x the density; the ultimate or nascent ratio of the above increments will be $\frac{du}{dx}$, in which dx is constant, the parts of the increment being equal. Again because the pressure at T is given, and the ethereal atoms have a perfectly free communication between the two vesssls, and the tenacious atoms in the inner vessel are separated by intervening ethereal matter; the initial resistance to any increment of density, that is the re-action of the ethereal matter, between the tenacious atoms, is always the same, being in equilibrium with the given pressure at T; therefore du is constant; hence it follows that $\frac{du}{dx} = a$ where a is a constant. Therefore $u = ax$, which needs no correction, because when the compressing force at P is nothing, the density of the tenacious atoms at the surface is nothing (prop. 2, case 7): therefore u varies as x; that is the compressing force is proportional to the density.

Scholium. It might perhaps at first seem strange to some, that the limit of the ratio of the compressing force and the density, should always be the same, and yet that the actual resistance, to a finite increment of the compressing force, should vary; but this difficulty will vanish by a little attention to the 2nd. prop. which shows that the tenacious atoms are invested with atmospherules of ethereal matter increasing in density to the surface of repulsion; hence as these approach up to a certain term, there will be a denser and greater portion of ethereal atoms to be resisted, and pressed against the spheres of repulsion, and forced out from between the atoms, than when the distance is greater.

Cor. 1. During compression ethereal matter will be continually given out from the inner vessel; and as the compressing force is diminished such matter will be absorbed. (2)

Cor. 2. After a certain limit of compression, two contiguous tenacious atoms will enter into union.

For after a certain degree of compression, causing the spheres of repulsion to intersect, the atmospherules will begin to be expelled from the line joining the atoms, hence after a certain limit these atoms will rush together, and consequently combine.

Cor. 3. Hence when a gas is liquified by compression, the main body of the gas will become liquid at once; since, in common circumstances, the pressure is nearly equal throughout the vessel, so that the point of equilibrium is attained nearly at the same time in every part. (3)

Cor. 4. When a gas liquifies, a great quantity of ethereal matter will in general be given out; as is evident from the preceding Cors. (4)

Cor. 5. In some cases, when the condensation takes place, the mass may become a solid.

Cor. 6. The compressing force varies inversely as the volume; since the density varies in that ratio.

Proposition 5. *Things being as in the last proposition, the resistance between two tenacious atoms, arising from the mutual actions of the mass, is inversely as the distance between the atoms.*

For since the compressing force varies as the density, (prop. 4.) and the density varies inversely as the cube of the distance between adjacent atoms, (Geom.); it follows, that the compressing force varies inversely as the cube of the distance between the atoms; but this also varies as the number of atoms on a given surface, and the force of each: now the number of atoms on a given surface is inversely as the square of the distance between them; therefore the force of each is inversely as that distance.

Cor. 1. Immediately before a gas becomes a liquid by compression, the compression will be less than as determined by the above law; because when the spheres of repulsion intersect, and ethereal matter is repelled from the common part, the above law will cease, and this happens immediately before liquefaction.

Cor. 2. The resistance to the compression of a liquid, will be very much greater than to that of a gaseous body, and will follow a different law.

For in this case the repulsion between the tenacious atoms themselves must be opposed, and this is vastly greater than that of the ethereal atoms.

Def. 1. The pressure at T answers to the effect of temperature, and that at P to the common pressure on gases, as may be gathered from prop. 2. cases 8 and 9, in conjunction with local and adventitious circumstances. Hence the pressure at T may be called the pressure of temperature; and that at P the pressure of re-action: or simply the temperature and pressure.

PROPOSITION 6. *The pressure, or re-action at P, being given; the volume will vary as the temperature.*

For when the volume is given, the pressure at P varies as the temperature, or pressure at T, (prop. 3. cor. 2,) also when the temperature is given, the pressure varies inversely as the volume (prop. 4, Cor 6); therefore when both vary, the pressure varies as the temperature directly, and the volume inversely; and consequently when the pressure is given the volume varies as the temperature. (5.)

Cor. 1. If any temperature T, and its corresponding volume V, be taken, v being the increment of an unit of volume for one degree of temperature, taken at T, also t a given increment of temperature from the term T: then $T : T + T v t :: V : V + V v t = V(1 + v t) =$ V' the volume at the temperature $T + t$.

Sch. If $T = 32°$ Fahr. T' any other temperature, and $V =$ the volume at 32°; and V' at T'; then $v = \frac{1}{480}$ by experiment; and therefore we have $V = \frac{480\,V'}{448 + T'}$, and $V' = V \cdot \left(\frac{448 + T'}{480}\right)$; similarly, $V'' = V\left(\frac{448 + T''}{480}\right) = \frac{480\,V'}{448 + T'} \times \frac{448 + T''}{480} = V'\left(\frac{448 + T''}{448 + T'}\right)$, or $V' : V'' :: 448 + T' : 448 + T''$.

If the zero in Fahrenheit's scale were marked 448° then—448 would have been the present zero: call the above the natural zero; and the temperature, reckoned from it, the natural temperature, in this case the freezing point would have been 480, and the boiling point 660, and we should then have V' : V'' :: T' : T,'' where V' is the volume of a given quantity of gas at the natural temperature T,' V'' its volume at T,'' which would render the calculations for volumes and temperatures easy. In this case the reciprocal of the temperature would express the augmentation of one volume for one degree at that temperature. The natural temperature is obtained by adding 448 to the temperature as expressed on Fahrenheit's scale, and that of Fahrenheit's from this by subtracting 448. Similar adaptations may be applied to other scales, thus the natural zero for the centigrade thermometer would be 267 degrees below the present zero of that scale.

This will not hold for extreme cases, as appears from prop. 5. cor. 1. also, in cases determined by experiment, corrections will sometimes be

required for the expansion of the vessels, alterations of pressure during the experiment, or other circumstances.

Example. What space would 100 inches of gas at 50° occupy, if raised to 60?

448 + 50 : 448 + 60 :: 100 : 102 the answer.

PROPOSITION 7. *The number of ethereal atoms of the same kind, in the line which connects two adjacent tenacious atoms, in a gaseous body, will vary as the square root of the absolute force of the tenacious atoms.*

Let a and b, fig. 2, be the tenacious atoms; then however their forces are varied, the atom z, when the forces, resolved as in prop. 2. case 3, are equal and opposite, remains undisturbed; but any other atom in $a\,b$, as d, is pressed towards the contiguous atom v, by the difference of the forces in R N, and therefore in the ratio of these forces: first let the forces of a and b be increased four-fold; then the distance between d and v will be diminished one half; because at one half the distance, the repulsion is four-fold, (1st prin.), therefore the number of atoms in $a\,b$, is doubled, since their distances are halved: similarly, if the forces were increased ninefold, the number of atoms would be trebled: and generally, it may be shown that the number of atoms of the same kind in $a\,b$, will be as the square root of the absolute forces of a and b. But in order to maintain a stable equilibrium to the increased number of atoms and tension, there will be required a proportional increase in the number and tension of the contiguous atoms: now this will evidently be supplied by the corresponding actions of a and b in the lines, or rays, of atoms, as they diverge in position from those centres, in lines close to $a\,b$: and thus, while the same pressures at T and P are continued, the equilibrium will be maintained through the medium by the proportional increase of the actions and re-actions which ensue. The actions of a and b on moderately distant atoms being exceedingly minute, or inappreciable, (prop. 2. case 2) need not be considered.

PROPOSITION 8. *If the absolute forces, or the spheres of repulsion (within certain limits) of the tenacious atoms, in a gaseous body, be varied, the force tending to keep the atoms apart, as in prop. 5, will not be altered; so that the pressure between the atoms, and on the sides of the vessel will continue the same.*

For this separating force, or the pressure on the sides of the vessel depends not on the absolute forces or on the spheres of repulsion (when these are not varied beyond the limits mentioned prop. 1. cases 6 and 7,) but on the pressure at T, and the distance between the atoms.

Or thus. Let one of the atoms be increased, in its absolute force, in any ratio; then the force between it and every atom in the vessel will be increased in the same ratio: therefore the equilibrium between the attractions and repulsions continues the same; that is, a variation in the absolute force produces no change in the tendency of the atoms to separate. Again, if the absolute force be given, the distances between the centres will continue the same, if the sphere of repulsion be varied within the limits above mentioned.

Def. 2. A single group of atoms is a collection of two or more tenacious atoms, such, that all their centres are within the sphere of repulsion of some one of them.

Def. 3. A double group is two atoms, or two single groups, or one atom and a single group; connected by a third atom or single group, such that the connecting atom or group displaces the greatest part of the ethereal and electric atoms between those which it connects, and the parts of their atmospherules on the sides between them.

Cor. 1. Considering a single group as one atom, and each double group as two atoms; there will always be an equal number of atoms in equal volumes of any gaseous bodies, the pressure being given. For, 1st, when the atoms are distinct and single, this follows from the 5th, and present propositions; from which it appears that when the pressure is given, the distance between the atoms, and consequently their number will be the same, whatever may be their absolute forces, and spheres of repulsion, so that the gaseous form continues.

2nd. It is manifest from the same propositions that a single group will occupy a volume the same as that occupied by a single atom: for since the centres of all the atoms in the group are within the sphere of repulsion of one of them, the centre of gravity of the group, may be considered as the centre of a single atom, and the contour of the spheres of repulsion as the surface of repulsion; hence it will have a distinct atmospherule and will act as a single atom, and will therefore evidently occupy the same volume in a gas. (6.)

3rd. In the case of double groups, since the connecting atom or group is not separated by intervening ethereal matter, it can only supply the place and effect of the matter it has displaced, and therefore the centres of the conjoined atoms or groups will be at the same distance as if the connecting atoms were replaced by the ethereal matter.

Cor. 2. When two atoms are connected chemically, yet so as not to form a single condensed group, they will occupy in a gaseous body, the same volume as they did before combination.

For by this and the 5th proposition they are kept at the same distance from each other, as they were before combination.

The link which connects them chemically will be noticed hereafter, (see observations to prop. 17,) this kind of union may more properly be termed cohesive combination.

Cor. 3. A double group will occupy in a gaseous body exactly twice the volume of one atom, or of a single group, as the first cor. shows.

Cor. 4. When gases are mixed together, and no chemical union takes place, or only cohesive combination, the volume is not changed, as is evident from the above. (7.)

Cor. 5. When the volumes, pressures, and temperatures of two gases are the same, then, however these are varied, so long as any two of them are the same, the third will be the same in both gases. (8.)

Cor. 6. If two gases have the same temperatures and volumes, but are under different pressures, then if the temperatures and volumes be varied alike in both gases, the ratio of the pressures will remain, and when the pressures are varied, but so that the same ratio of the pressures remains, then, if the volumes are equal, the temperatures will be equal; and the converse. (9.)

For if the volumes remain the same, the pressures will vary as the temperatures, (prop. 3. cor. 2.) therefore for the same variation in the temperatures of the two gases, there will be a proportional variation of the pressures, and therefore the ratio of the pressures will not be altered; thus if the pressure of one be doubled, trebled, &c. that of the other will also be doubled, trebled, &c. Again, if the temperature continue the same, the pressure varies inversely as the volume (prop. 4. cor. 6.) therefore still the ratio of the pressures remains, when the volume continues the same in both. It follows that when both the temperature and volume are varied the same in both, the ratio of the pressure in the two gases is not varied. The other part of the cor. is evident.

Scholium. If an objection be made to this proposition and its cors. by an appeal to fact, that the specific gravity of sulphur vapour is 96, hydrogen being 1, while the atomic weight of sulphur is only 32; it is easily obviated; for there will be a perfect agreement, if the vapour of sulphur consists of simple groups of three atoms each: and this is likely, since sulphur has two freezing points, and the liquid is less limpid after the 2nd, than after the 1st; besides other peculiarities.

If the atomic weights of phosphorus and arsenic be 16 and 38, their vapours are in single groups of four atoms each, probably in tetrahedrons, rendering them isomorphou

Proposition 9. *Things being as in prop. 5th and 6th, if the compressing force be removed, as by an aperture in the side of the vessel, the contiguous atoms will begin to separate by a force inversely proportional to the square root of their absolute root.*

For at the commencement of the motion, the separating force is reduced to the actions of the atoms between *a* and *b*, fig. 2. the aperture being at N, in the line *a b*; and therefore it depends on the number of atoms of a given sort situated in the line between *a* and *b*; but this number, and consequently the moving force, is as the square root of the absolute force of *a* and *b*; (prop. 7): also, the quantity of matter moved is as the absolute force of these atoms, since this force measures the mass: therefore (by Mech.) the accelerating force is as the square root of the absolute force directly, and as the absolute force, or the mass inversely; therefore the accelerating force is as the square root of the absolute force inversely.

Cor. 1. Hence the atoms would flow into a perfect vacuum, with velocities inversely proportional to the square roots of their absolute forces; hence also ethereal atoms will flow into a perfect vacuum with a very much greater velocity than that of tenacious atoms.

Cor. 2. If tenacious atoms in the two compartments of the vessel (fig. 2.) be of the same sort and density, they will not flow through an aperture from the one to the other, which is evident from this, that there is an equilibrium, and also an uniformity of disposition in the acting forces.

Cor. 3. If the inner vessel contain tenacious matter in a gaseous form, and the exterior compartment ethereal matter only; the tenacious atoms would issue through an aperture, with a velocity inversely proportional to the square root of the density of the gas. (10.)

It is evident that an aperture being made, motion will ensue, and because of the perfect elasticity of the ethereal matter, the centre of one of every two contiguous atoms being within the sphere of repulsion of the other; the velocities communicated in any elements of time, will be preserved; but because of the given resisting medium, the increments of velocity will be diminished, in a given time, by parts proportional to themselves: hence the ratio of the velocity will remain, while the real velocity becomes less.

Proposition 10. *If two sorts of gaseous matter occupy distinct and separate parts of the inner vessel; they will diffuse themselves mutually, till they are uniformly disposed through the vessel: and one sort being given, the other will diffuse itself with a velocity inversely proportional to the square root of its density.*

For the adjacent tenacious atoms are equidistant in both gases, and are kept apart by equal resistances (prop. 5 and 8,) but because of their different absolute forces, the ethereal matter is less dense in the one case, than in the other (prop. 7,) hence the atoms of one sort will pass between those of the other, when any agitation or disturbing action occurs, till the whole are uniformly disposed. Had the spaces between the atoms of one sort been a perfect vacuum, the other would have passed with velocities inversely as the square root of the absolute forces (prop 9. cor. 1); but in the real case, there is a resistance by which the velocities are diminished by parts proportional to themselves (prop. 9, cor. 3.) hence the velocity of diffusion will be less, but still the atoms will diffuse themselves among the others, with velocities inversely proportional to the square roots of their absolute forces, or their densities, since by prop. 8, and its cors. the densities of gases under the same pressure are as the absolute forces of their atoms. (12.)

Scholium. The actual velocity of diffusion will be affected by circumstances, such as the magnitude of the spheres of repulsion, agitation, extraneous forces, &c. yet in general the diffusion will be more rapid with light, than with heavy gases. (13.)

Proposition 11. *Other things being the same, a body in the gaseous form, will more easily take the liquid, or solid form, when the tenacious atoms have a greater absolute force.*

When the gas is in a state of perfect equilibrium, the tenacious atoms are kept apart, by an equal repelling force, whatever may be their absolute forces, (prop. 8, and cors.); but the perfect equilibrium is easily disturbed, because the most dense part of the ethereal matter is (prop. 2,) in the lines which join their centres, hence a slight agitation, or other disturbing cause, will destroy the equilibrium, which will be regained with less facility, as the tenacious atoms have a greater absolute force: 1st, because the ethereal matter relatively opposes a less resistance to their motion: and 2nd, because their greater force tends to bring them together with greater energy and rapidity; hence they will more readily take the liquid or solid form.

Cor. It is easily seen from this, that when the temperature, pressure, and spheres of repulsion of the tenacious atoms are given; the absolute forces may be so great, that they cannot retain the gaseous form, but will appear as liquids, or as solids; hence it is obvious why, at common temperatures, we have the varieties of the gaseous, liquid, and solid forms.

Proposition 12. *When the spheres of repulsion of the tenacious atoms are greater, other things being the same; the gaseous form will be sustained with greater firmness and constancy.*

For the larger sphere of repulsion occupies a larger portion of the given distance between two contiguous atoms; hence the equilibrium is less disturbed by a given cause, and is more easily restored; also the resistance to the motion of the atoms in the ethereal matter is greater: therefore the gaseous form is maintained with greater energy.

Proposition 13. *Other things being the same, the liquid or solid form is attained more easily, as the pressure is greater, and the temperature is less.*

For when the pressure is greater, the tenacious atoms will be urged towards each other, with a greater force, when any disturbance of the equilibrium occurs: also when the temperature is less, the gaseous form, as appears from prop. 6 and 8, is more feebly supported, and consequently the liquid or solid form sooner attained. (14.)

Proposition 14. *To show the general condition requisite for the gaseous, liquid, and solid forms of bodies.*

1. First, while there is a body of tenacious matter retained between the surfaces of repulsion of contiguous atoms, whether these are simple atoms, or single, or double groups, the gaseous form will be supported, since there is nothing to prevent the free expansion and contraction of the mass, when the pressure is varied.

2. Next let the pressure and temperature, and other relations, be such, that the spheres of repulsion intersect; then the ethereal matter will be repelled from the common part, which will appear by resolving the forces as in prop 2nd, and at a certain point the atoms will rush together, and produce a change of form, (prop. 4, and cors.), at this moment, it is manifest, that a considerable quantity of ethereal matter will be discharged: also in some cases double groups will become single ones. And by the last proposition, this will happen sooner if the pressure be increased, or the temperature diminished.

3. Hence when the temperature, and volume are given, and the pressure such, that the least increase of pressure would begin to reduce some part of the gas to a liquid form, then for every additional quantity of gas introduced into that space, an equal quantity will be condensed into the liquid form, the rest retaining the form of gas. Hence at a given temperature, a determinate portion of a liquid occupying part of a given vessel, will be found in the form of vapour, and this quantity will become greater as the temperature increases. (15.)

4. Again let the temperature of a liquid be diminished; while this

proceeds, evidently ethereal matter will escape, producing a contraction chiefly at the surface; and, it is easily seen, that at a certain term of the process, the superficial atoms will approach, at some places, so as to impede, and interrupt the escape of the ethereal matter at those places; it will therefore now pass in other intervals, swelling or extending the pores in its new passages, which increases the contractions in the former places. Thus the atoms and groups, being fixed at certain points will constitute a solid, more or less hard or soft, brittle or flexible, elastic or otherwise, according to the sorts of atoms, or particles, and their mode of union. It is also evident that the solids, so produced, may be greater or less in volume, than the original liquid, and in general will be crystallized, if undisturbed. (16.)

5. But even in the liquid and solid forms, there will be much ethereal matter on the exposed surfaces of the spheres of repulsion, and a large quantity condensed, by their mutual repulsions, in the spaces, or parts of the spheres of repulsion which are common to three or more tenacious atoms.

Sch. This accounts for the extrication of caloric from solids by percussion, and friction, which in some cases produce a permanent increase of specific gravity.

Cor. The dilatations of liquids will in general be greater in high than in low temperatures, and this will be different in different liquids. (17.)

For, because the centres of the atoms are much nearer in the liquid than in the gaseous form, (in water about 12 times nearer) in general the spheres of repulsion will extend beyond the centres of contiguous atoms, and sometimes beyond those of the 2nd or 3rd stratum from it, (see prop. 1. case 7,) and the effect of the separating force will be less between those atoms whose centres are so disposed, as appears by case 2nd, of this prop. hence as the liquid expands by an increasing temparature, the separating force becomes more effective, and the enlargement is greater in higher temperatures.

PROPOSITION 15. *If ethereal and electric atoms be compressed in a vessel (fig. 2) the pressure and temperature being given: then if the absolute force of one of the tenacious atoms be given, while its sphere of repulsion varies; there will be a certain magnitude of its sphere of repulsion, at which it will collect and retain a maximum quantity of electric atoms on its surface of repulsion.*

For, 1st, let the sphere of repulsion be extremely small, then the attraction at the surface is very great, (1 prin.), therefore, the density of the ethereal matter at the surface is also very great, (prop. 2.) and, therefore, the electric atoms at the surface obtain a more condensed atmospherule of ethereal matter, (prop. 2, case 6), hence the relative attraction between the tenacious and electric atoms is diminished by their united actions on the adjacent ethereal matter, and this together with the extremely small surface of repulsion, will operate against the firm attachment of the electric atoms, which will, therefore, the more readily pass off to the other neighbouring tenacious atoms.

2nd. Next, let the sphere of repulsion be very large; then at the

surface of repulsion, the force is very small, and therefore the electric atoms are loosely retained; and hence, when any disturbance occurs, they will pass off to other tenacious atoms, having their absolute forces and spheres of repulsion better proportioned to retain them.

From these two parts it follows, that when the absolute force of the atom is given, there is a certain magnitude of the sphere of repulsion, at which it will retain a maximum quantity of electric atoms.

Cor. 1. When the pressure and temperature are given, there is a fixed and definite relation between the tenacious atoms of bodies, and those of the electric fluid attached to them, as to quantity. (18.)

Cor. 2. When the temperature is varied, the relation between the tenacious and the electric atoms, is in some degree altered. (19.)

For the densities of the ethereal atmospherules will be varied in different ratios, on account of their different absolute forces, and spheres of repulsion.

Cor. 3. From this it appears, that a variation of the temperature will alter the electrical relations of elements, and consequently, their tendency to combine. (20.)

PROPOSITION 16. *When bodies combine chemically; the ratio of the quantities by weight are fixed, and definite, and such as may be expressed in small whole numbers.* (21)

Since tenacious atoms, in common circumstances, are always situated in a compressed body of ethereal matter; they will be encompassed by distinct atmospherules, (prop. 2. case 4.) this evidently tends to keep them apart; and hence, there can be no combination unless one or more of the atoms, or groups penetrate the atmospherules of the others, so as to form a single group: or that they are connected by some intermediate link, as either another tenacious atom or group, or some intervening electric atoms, which may collect between them, (prop. 2, case 5.) When this change is effected, the new particles will be invested with a distinct common atmospherule, (prop. 8 and 2): hence, if this new particle can combine with an additional quantity of the same element, it will be with another atom or group, so that entire atoms or groups will in general evidently combine; and after a certain quantity of the given body has entered into union, the more condensed atmospherule of the augmented atom will tend to prevent the combination of more atoms of that kind, except by cohesion: hence the proportions will be simple, and such as may in general be expressed by small numbers.

Cor. When atoms, or groups of one kind, combine with groups of another kind, frequently, some atoms of the groups will be excluded, or decomposition will occur.

PROPOSITION 17. *Taking each elementary atom as representative of a volume; then in all chemical combinations, that is, whenever there is a condensation, the resulting volume is always, either one or two volumes exactly, whatever number of atoms or volumes combine.*

For, since the volume is diminished, the centre of some one of the atoms, or those of several of them, have penetrated the atmospherule of some other, (prop. 8, and cors.)

1. When the atmospherule of one atom or single group is penetrated by the centres of all the other atoms, the result is a single group, and consequently (prop. 8) that result will be one volume exactly.

2. When one atom, or single group combines with a single group, and all the centres do not rest within the sphere of repulsion of one of them; then one or more of the atoms will be brought by their mutual actions, to the interval between the remaining atoms, or single groups, which combine, and so situated will (prop. 8, cor. 3) supply the effect of the ethereal and electric matter, which is displaced, or removed from between them; hence the collection will form a double group, and (by the same cors,) will become two volumes exactly.

3. When one atom, or single group combines with a double group, the centres of the combining atoms of the single group, or that of the single atom, will penetrate the atmospherule of the double group; otherwise there would be only a cohesive combination, or none; therefore the whole, when combined, will continue a double group, and form exactly two volumes (prop. 8, cor. 3); except when the mutual actions bring all the centres within the sphere of repulsion of one of them, in whieh case (prop. 8, cor. 1,) they will become exactly one volume: hence still we have either a single or double group, so that evidently no other case can occur: therefore the resulting volume will be exactly one or two volumes in all cases, however many atoms or volumes thus combine.

Cor. This proposition includes Gay Lussac's theory of volumes, which it explains, simplifies, and extends. (22).

The important law contained in this proposition, in its whole extent, has not been before determined, although approaches towards it have been made in the theory of volumes: after the discovery of that theory, by Gay Lussac, a striking relation between the atomic weights of bodies in the gaseous form, and their specific gravities, could not long remain unobserved, and this was particularly noticed by Dr. Prout: but the exact and remarkable law just demonstrated, I believe has never been shewn in its generality, though many particular cases have been established, as insulated facts; and experiments, as far as they go, serve to establish the above proposition, which would have been equally valuable, had it been fully shewn as an experimental ultimate fact, for even then, the fact would have been utterly inexplicable by any of the admitted theories.

This proposition shews in what manner atoms may be combined, and also that frequently the combinations of the same atoms may admit of different forms producing isomeric bodies; for example, hydrogen and carbon combine in four different ways in the ratio of one to six by weight, as in methylene fig. 13, olefiant gas fig. 7, and oil gas fig. 16, etherine fig. 10, being nos. 14, 19, 37, and 62, in the table; also when the manner in which the atoms combine is known, the resulting volume may with ease and perfect certainty be predetermined.

Having deduced this exact and invariable law from my two simple principles, it became exceedingly important to ascertain, if it is really true in fact to this extent and generality. To determine this point I

calculated what would be the specific gravities of a great number of compounds according to this law, supposing they could be obtained in the gaseous form, taking the atomic weights as given in the table; then comparing the results with all those which I could find had been determined by experiment: these compound gases and vapours amounted to 57, which I put in a tabular form, and have since augmented the number to 68, from which it is seen that there is a complete agreement within the allowable errors of such experiments, except in boro-chloric acid, which Dr. Thomson says requires farther investigation, and a small discrepancy in oil of turpentine: but probably the true composition of these substances has not been accurately determined, or otherwise some foreign ingredients may have been in the specimens tried.

To make the calculations, all that is necessary is to add together the atomic weights of the elements, which combine, and multiply the sum by ·0964, the specific gravity of hydrogen, which gives the specific gravity required, when the elements combine in single groups,: but it is half that product, when they combine in double groups: when there is only a cohesive combination, which rarely happens, then the product must be divided by the number of atoms; since according to this law, cohesive combination never alters the volume, a circumstance which cannot be accounted for by any other acknowledged principles.

A Table Containing the Three Varieties of Chemical Compounds.

I.—COHESIVE COMBINATIONS.

Name.	Elementary Atoms. Number.	Elementary Atoms. Weight.	Wt of comp. atom.	Vol.	Sp. gr. hyd=1	Sp. gr. air=1 By Cal.	Sp. gr. air=1 ByExper	Authority.
1. Carbonic oxide	C + O	12 + 16	28	2	14	·972	·973	Thenard.
2. Nitre oxide	N + O	14 + 16	30	2	15	1.041	1·037	Ditto.
3. Muriatic acid	Cl + H	36 + 1	37	2	$18\frac{1}{2}$	1·284	1·248	Biot&Arago
4. Hydrobromic acid	Br + H	80 + 1	81	2	$40\frac{1}{2}$	2·812	2·731	Turner.
5. Hydriodic acid	I + H	126 + 1	127	2	$63\frac{1}{2}$	4·409	4·443	Gay Lussac.
6. Bisulphuret of mercury	S +2 M	32 + 200	232	3	$77\frac{1}{3}$	5·370	5·384	Dumas.
7. Common air	O + 4 N	16 + 56	72	5	$14\frac{2}{5}$	1	1	Theassumed unit.

II.—CHEMICAL COMBINATIONS IN SINGLE GROUPS.

Name.	Elementary Atoms. Number.	Elementary Atoms. Weight.	Wt of comp. atom.	Vol	Sp. gr. hyd=1	Sp. gr. air = air By Cal.	Sp. gr. air = air By Exper	Authority.
8. Cyanogen	N + C	14 + 12	26	1	26	1·805	1·806	GayLussac
9. Dichlo^e. Sul.	S + Cl	32 + 36	68	1	68	4·722	4·70	Dumas
10. Fluoboricacid	F + B	18 + 16	34	1	34	2·361	2·360	Davy.

III.—CHEMICAL COMBINATIONS IN DOUBLE GROUPS.

Name.	Elementary Atoms.		Wt of comp. atom.	Vol	Sp. gr. hyd=1	Sp. gr. air=1		Authority.
	Number.	Weight.				By Cal.	By Exper.	
11. Biniodide mer.	I + Hg	126 + 100	226	1	226	15·694	15·67	Mitscherlich
12. Bichloride mer.	Cl + Hg	36 + 100	136	1	136	9·444	9·44	Ditto
13. Bibromide mer.	Br + Hg	80 + 100	180	1	180	12·500	12·360	Ditto
14. Olefiant gas	C + 2 H	12 + 2	14	1	14	·972	·978	Henry.
15. Fluosilicic acid	Si + 2 F	16 + 36	52	1	52	3·611	3·60	Thomson.
16. Chloride silicon	Si + 2 Cl	16 + 72	88	1	88	6·111	5·939	Dumas.
17. Nitrous acid	N + 2O	14 + 32	46	1	46	3·194	3·177	Gay Lussac.
18. Hydrocar^{t}. chlo.	Cl + (C + 2 H)	36 + 14	50	1	50	3·472	3·443	Ditto.
19. Etherine	2 C + 4 H	24 + 4	28	1	28	1·944	1·91	Faraday.
20. Bicarburet. hy.	3 C + 3 H	36 + 3	39	1	39	2.708	2·776	Ditto.
21. Oxalic ether	3C + 5H + 2O	36 + 37	73	1	73	5·069	5·08	Brande.
22. Naphtha	3 C + 5 H	36 + 5	41	1	41	2.847	2·833	Sassure.
23. Napthaline	5 C + 4 H	60 + 4	64	1	64	4·444	4·528	Dumas.
24. Camphene	5 C + 8 H	60 + 8	68	1	68	4.722	4·767	Ditto.
25. Oil turpentn.	6 C + 8 H	72 + 8	80	1	80	5·555	5·013	Gay Lussac.
26. Arsenous acid	4 As + 3O	152 + 48	200	1	200	13·888	13·67	Dumas.
27. Acetic ether	O + 2 olef	16 + 28	44	1	44	3·055	3·06	Ditto.
28. Water	O + 2 H	16 + 2	18	2	9	·625	·628	Gay Lussac.
29. Sulphuretted hy	S + 2 H	32 + 2	34	2	17	1·180	1·19	Thenard.
30. Telluretted hy.	Te + 2 H	64 + 2	66	2	33	2·292	2·292	Brande.
31. Carbonic acid	C + 2O	12 + 32	44	2	22	1·527	1·519	Thernard.
32. Sulphurous ac.	S + 2O	32 + 32	64	2	32	2·222	2·255	Berzelius.
33. Chloride of sul.	S + 2 Cl	32 + 72	104	2	52	3·611	3·67	Dumas.
34. Nitrous oxide	O + 2 N	16 + 28	44	2	22	1·527	1·522	Thenard.
35. Bisul. carbon	C + 2 S	12 + 64	76	2	38	2.638	2·644	Gay Lussac.
36. Borochloric ac.	B + 2 Cl	16 + 72	88	2	44	3·055	3·942	Dumas.
37. Methylene	C + 2 H	12 + 2	14	2	7	·486	·490	Ditto.
38. Protoxide chlo.	O + 2 Cl	16 + 72	88	2	44	3·055	3·0	Gay Lussac.
39. Deutox. chlo.	Cl + 2O	36 + 32	68	2	34	2·361	2·346	Thenard.
40. Protochlor mer.	Cl + 2 Hg	36 + 200	236	2	118	8·194	8·20	Mitscherlich
41. Bromide mer.	Br + 2 Hg	80 + 200	280	2	140	9·722	9·665	Ditto.
42. Hydrocy. acid	H + (N + C)	1 + 26	27	2	$13\frac{1}{2}$	·937	·947	Gay Lussac.
43. Chlorocy. acid	Cl + (N + C)	36 + 26	62	2	31	2·152	2·153	Dumas.
44. Ammonia	N + 3 H	14 + 3	17	2	$8\frac{1}{2}$	·590	·597	Biot & Arago
45. Sulphuric acid	S + 3O	32 + 48	80	2	40	2·777	3·0	Mitscherlich
46. Inflam. gas of Dr. Thomson.	3 Cl + olef.	108 + 14	122	2	61	4·236	4·175	Thomson.
47. Phosphor. hy.	2 P + 3 H	32 + 3	35	2	$17\frac{1}{2}$	1·215	1·214	Dumas.
48. Arsenuret. hy.	2 As + 3 H	76 + 3	79	2	$39\frac{1}{2}$	2·743	2·695	Ditto.
49. Chlo. phos.	2 P + 3 Cl	32 + 108	140	2	70	4·861	4·875	Ditto.
50. Chlo. arsenic	2 As + 3 Cl	76 + 108	184	2	92	6.388	6·30	Ditto.
51. Percholide tin.	Tn + 4 Cl	116 + 144	260	2	130	9·027	9·199	Ditto.
52. Perchlo. titan.	Ti + 4 Cl	52 + 144	196	2	98	6·805	6·856	Ditto.
53. Light car. hyd.	C + 4 H	12 + 4	16	2	8	.555	·559	Henry.
54. Perphos. hyd.	3 P + 3 H	48 + 3	51	2	25	1·770	1·761	Dumas.

Name.	Elementary Atoms.		Wt of Comp. atom.	Vol	Sp. gr. hyd=1	Spr. gr. air=1		Authority.
	Number.	Weight.				By Cal	By Exper	
55. Alcohol	Aq + 2 olef	18 + 28	46	2	23	1·597	1·613	Gay Lussac
56. Protohy. methy.	Aq + ether	18 + 28	46	2	23	1·597	1·60	Dumas.
57. Ether	Aq + 2 ether	18 + 56	74	2	37	2·569	2·586	Gay Lussac
58. Nitric acid	2 N + 5 O	28 + 80	108	2	54	3·75	3·75	Henry.
59. Pyroacetic sp.	O + 3 olef.	16 + 42	58	2	29	2·014	2·017	Dumas.
60. Pyroxylic spirit	Ag + olef.	18 + 14	32	2	16	1·111	1·115	Brande.
61. Mur. methyline	(Cl + H) + olef	37 + 14	51	2	$25\frac{1}{2}$	1·77	1·736	Dumas.
62. Oil gas	3 C + 6 H	36 + 6	42	2	21	1·458	1·458	Henry.
63. Paranapthaline	15 C + 12 H	180 + 12	192	2	96	6·666	6·741	Dumas.
64. Citrene	5 C + 8 H	60 + 8	68	2	34	2·361	2·383	Dumas.
65. Camphor	O + 2 citr.	16 + 136	152	2	76	5·277	5·29	Ditto.
66. Chlo. car. acid	2Cl + (O + C)	72 + 28	100	2	50	3·472	3·472	Henry.
67. Muriatic ether	H + Cl + 2 olef	37 + 28	65	2	$32\frac{1}{2}$	2·256	2·219	Thenard.
68. Hydriodic ether	H + I + 2 olef.	127 + 28	155	2	$77\frac{1}{2}$	5·381	5·474	Gay Lussac

Cohesive combinations rarely attain the character of chemical compounds; the only known substances of this kind, as yet well established, are the first six in the table: it has been disputed amongst chemists, whether the seventh, or common air, is to be reckoned as a chemical combination or not: but it has been generally allowed, that in all mixed gases, some degree of cohesion exists, and this is a necessary consequence from the second proposition (23). The cohesion becomes powerful, and involves the two atoms in one atmospherule when one at least of the elements has an abundant quantity of electric atoms in its atmospherule, (see prop. 15, and cors.), so that when contiguous, the electric atoms come chiefly between them (see prop. 2, case 5), and form the combining link: this is well illustrated in muriatic acid. A mixture of chlorine and hydrogen is represented in fig. 3, and the same combined is muriatic acid, as in fig. 4. To this agree all the phenomena attending the formation of this compound; the chlorine, *c*, is 36 times greater in force than the hydrogen, *h*, and its sphere of repulsion probably less, hence it will retain a large quantity of electrical atoms, and while the mixture is perfectly still; the equilibrium and places of the atoms ought to remain (prop. 2), but by the same proposition, the equilibrium in respect of the electric atoms, not being a stable one, when any disturbing cause affects the mixture, as the action of caloric, light, &c. the electric atoms will be brought to the interval between *c* and *h*, and will thus involve the two atoms in the same atmospherule as in fig. 4; causing at the same time an evolution from between the atoms, especially of caloric and light, which had been before condensed on the chlorine. (24.) By supposing a suitable alteration in the absolute forces, and spheres of repulsion of the two atoms, fig. 4, will represent the compounds in the table from No. 1 to 5 inclusive, fig. 5, represents No. 6, fig. 6, represents similarly Nos. 8 to 13, only that in 12 and 13 the surface of the mercury will rest on the centre of the other. Fig. 7 represents Nos. 14, 15, and 16. Figs. 8, 9, and 10, are Nos. 17, 18, and 19, figs. 11 and 12 are Nos. 23 and

24, No. 25 is nearly the same having only an additional atom of carbon; perhaps it differs only by some admixture. Fig. 10 with an atom of oxygen situated as the smaller atom in fig. 6 would serve for No. 27: fig. 13, on the same principles, will represent Nos. 28 to 43, 16 compounds, which is the most general kind of combination, for the same figure would represent all the double groups, if we considered a single group as one atom, Fig. 14 will serve for No. 44, and for 45 by connecting with the sulphur and one atom of oxygen, and for 46 if two of chlorine be connected by one olefiant gas and one chlorine, Fig. 15 serves for Nos. 47, 48, 49, 50; Fig. 7 connecting two other atoms, the same as the two in the fig., having their centres near the intersections will be the figure for Nos. 51, 52 and 53, Fig. 15 with an additional atom of phosphorus near the centre will serve for No. 54. Fig. 16 answers for No. 62, and for 55 or 56; one of these is probably one etherine and one water, or fig. 10 and 15 connected. Fig. 17 is No. 57: Fig. 15 for No. 34 would serve for No. 58 by putting two more atoms of oxygen on each side of the connecting one in the figure, two of the centres lying a little within one of the atoms of nitrogen, and two within the other. The rest will be understood with ease.

It is manifest that the same atoms admit of various manners of combining, so as either to give the same, or a double, treble or quadruple density; and indeed this is a circumstance, which the theory would lead us to expect, while it cannot be satisfactorily explained on any other (25) Nos. 14, 19, 37 and 62 are isomeric; so are 23 and 63, and also 24 and 64; 55 56 are not only isomeric, but also of the same specific gravity; doubtless one of them is an atom of water connecting two of olefiant gas, and the other one of etherine, and one of water in a double group.

The combinations in Nos. 47, 48, 49 and 50 would lead us to suspect that phosphorus and arsenic are isomorphus, as they are in fact.

It may also be observed, that the single groups may be in combination as double groups; we have only to double the number of atoms, and let some of the resulting atoms connect the others; but the compounds given as double groups cannot be single ones, if the elements are truly assigned: yet it is possible, but not probable, that some of them may be single groups chemically connected by cohesive combination. We may see from fig. 8, that nitrous acid will readily yield a portion of its oxygen to substances easily oxidized; for the atom of oxygen attracts the nitrogen with the force of 16, and is repelled by the nitrogen with a force of 14; so that it is held only by the force of two which with the atmospherule shews that the oxygen is held loosely by the nitrogen; this circumstance will also be a key to explain many of the phenomena of nitrous acid (26). From the great difficulty of ascertaining the specific gravity of gases and vapours by experiment, it is not unlikely but that some of the above numbers will require correction, and perhaps the atomic weights have not in all cases been duly determined, there seems to be especially a great discordancy amongst chemists respecting phosphorus, the wonder is that the agreements in all known cases is so close and exact as appears from the table: and I am persuaded that as we arrive at

more accuracy in the experiments, the agreements with the theory will approach nearer to perfection.

Proposition 18. *To explain evaporation in general.*

Let a quantity of liquid be contained in a part of a close vessel to which ethereal matter has free access. Now the atoms of the liquid tend to keep together, and to maintain themselves in a separate body by their mutual attractions, and the resulting pressure on each other, and in some cases by external pressures: at the same time they tend to separate by the pressure of the ethereal matter present, and their attractions on that matter, tending to bring it between the contiguous atoms. When the ethereal matter is in quantity so small, that the forces, by which the atoms tend to keep together, exceed the separating forces whatever they may be, no atoms of the liquid can rise into the vacuous part of the vessel; but if the temperature be increased, the additional ethereal matter thus present will increase the separating force, which will cause some portion of the liquid to rise into the upper part of the vessel, and this will be more in quantity, as the temperature is higher, till the vapour raised, counterbalances the effect of the temperature.

Proposition. 19. *Things being as in the last proposition, when the temperature is such as to produce vapour; the higher the temperature, the more vapour will rise, and always the density of the vapour will be as the elastic force.*

Let *a f*, *j f*, fig. 18, be two spheres of repulsion of the tenacious atoms *c* and *h*, in contact, and the most elevated atoms in the common stratum between the liquid and vapour, on which the atoms of vapour press, either directly, or through the medium of the ethereal matter. The number of points pressed will be proportional to the number of pressing atoms in contact with a given part of the surface, and these points may be considered as equidistant in the plane of the surface, and acting with equal forces in a direction perpendicular to the surface. Let *a e* represent one of these equal forces, and let it be resolved into two, *a d*, *d e*, of which *a d* is towards the centre, and *d e* parallel to the tangent at *a*. Draw *d b* perpendicular to *a e*, and let *a d* be resolved into *a b*, *b d*; and *d e* into *d b*, *b e*; then *b d* and *d b* are equal and opposite, and are supported by equal forces from the sides *c* and *h*: hence these neutralize each other: of the remaining two, *a b* presses directly on the centre *c* of the atom, and its effect is to prevent the atom from rising: the other presses directly at *f*, and is effective only through the medium, or re-action of the ethereal matter, and the other tenacious or electric atoms at *f*, lower than *c* or *h*. This re-action is a force, which when resolved into the perpendicular and parallel directions with respect to the surface; the parts in the parallel directions will neutralize each other, and the other will act directly upward on *c*, tending to elevate the atom *c*. If *a* be 45° from the vertex *k*, then *a b* = *b e*, and if two points be taken on different sides equidistant from 45 , the sum of the two forces in *a b* will be equal to the sum of the two in *b e*. But of all the points pressed, there is an equal number on the one side as on the other, so circumstanced; therefore the direct pressure at *c* is equal to the whole direct pressure at *f*: but only part of that at *f* is effective to raise the atom *c*, as shown above: hence it is seen that the whole effect is a pressure downwards, directly on *c*, tending to produce, or with the cohesion, to preserve the liquid form.

Again, the force of the liquid on the same atoms of the common stratum is an upward force perpendicular to the surface, as will appear by resolving the forces as above, on the other side, that is in the opposite direction, and this with the attraction of the liquid on the adjacent ethereal matter tends to produce and preserve their gaseous form. If these opposite forces be not equal, the atoms of the common surface will become vapour, or liquid, according as the one or the other prevails.

Let them be in equilibrium, and let the temperature be a little raised, then both the direct forces will be increased, but that of the liquid most, because, 1st, there are more atoms of the liquid on a given surface, and 2nd, because the force of each is greater, since on account of their greater proximity they more powerfully attract the ethereal matter towards the point between them. Consequently some of the atoms of the common surface will be propelled into the vapour, and these will increase its direct action downwards, from which it appears that the process will go on till an equilibrium is attained: that is till the vapour raised exactly compensates the effect of the increment of temperature: thus always the vapour raised counteracts the effect of the increment of temperature by which it is produced, and that previously raised still balances the previous temperature.

Now let the vapour be contained in a given space, and since each portion of it always balances the same quantity of the force of the liquid by which it was produced, or the pressure which is equal to it, the whole quantity will be as the whole force or pressure, when there is an equilibrium; but the whole quantity is as the density, because the volume is given: therefore the density varies as the pressure, or as the elastic force.

Scholium. This proposition might have been deduced as an immediate consequence of prop. 4, but because of its importance a separate and independent proof was preferred: either this proof or that of the 4th prop. being admitted, the other is necessarily true. Indeed this proof was made before any thought of applying the 4th prop. occurred.

Def. 4. The perpendicular force of the liquid upwards with its attraction on the adjacent ethereal matter, may be called the evaporating force.

Def. 5. The perpendicular force of the vapour downwards together with the cohesion of the particles of the liquid may be called the liquifying force.

Cor. 1. It follows from this, as well as from prop. 4, that the atoms of a gas or vapour in consequence of the sum of the mutual actions repel each other with forces inversely as their distance.

Cor. 2. Vapours are governed by the same laws precisely as affect permanent gases; their production and condensation being allowed for. (27)

Cor. 3. When the temperature is given, the evaporation will go on till the vapours are of a given density, whatever may the space it occupies within moderate limits, a sufficient quantity of liquid being present.

Cor. 4. If the space containing the vapour be enlarged, more vapour will be produced, for the liquifying force is diminished, while the evaporating force remains the same: similarly if the space be contracted, part of the vapour will be condensed, since the liquifying force is increased, and its antagonist not altered; and in both cases the original density will be restored. (28)

Cor. 5. The common stratum between the liquid and vapour, when there is an equilibrium, is equally in a state to pass into the form of a liquid or vapour, just as the one or other force prevails, it is thus suspended between the two forms; and this stratum is of a greater or less thickness according to circumstances, being thicker at high temperatures.

Proposition 20. *When air or any permanent gas occupies the space above the liquid; then at a given temperature, the same quantity of vapour will be raised as in a common vacuum of the same dimensions.*

First, suppose the vapour removed, and any gas substituted in such quantity as to produce a pressure not less than the liquifying force: and so that the resultant pressures are at the same points: if now no extraneous or disturbing action occur, no vapour can rise: but on any slight disturbance of the equilibrium, gas will diffuse itself into the common stratum; and consequently vapour will diffuse itself from the common stratum into the gas, for the same reasons that different sorts of gas in contact diffuse themselves uniformly, (prop. 10.) and the process will continue till the force of the vapour can of itself counteract the evaporating force; because the gas and vapour already mixed, may be considered as gas in contact with the common stratum; but a greater quantity of vapour cannot exist in the gas, because if present, the liquifying would exceed the evaporating force, independantly of the gas, not only on the surface, but through the common stratum and body of the liquid. It is manifest the same would happen if the gas had at first a less density. (29.)

Cor. 1. It is seen from (prop. 10.), that the vapour will not be diffused through the gas so rapidly as through the vacuum, or through a less dense gass: and the evaporation will proceed slower as the vapour approaches the point of its density, due to the given temperature, not only because the rate of diffusion is less, but also because the pressure is greater. (30.)

Cor. 2. When the temperature is lower than a certain given degree, no vapour will rise.

For the atoms of the liquid, considered independently of the vapour, or external pressure, are kept together by their mutual attractions, and pressures; and they tend to separate by the pressure of the ethereal matter present, and their attractions on that ethereal matter: now as the temperature diminishes, the former force becomes greater, and the latter less, hence there will be a point of temperature where these are equal, and below this it is manifest no vapour can rise: this temperature is probably about 500° below the boiling point.

Cor. 3. When vapours, air, or any permanent gases, or any mixture of these, are in contact with the surface of the water, the liquifying force, which they produce, is propagated through the whole body of liquid, in consequence of the medium of the ethereal matter, since the centre of one of every two contiguous atoms is within the sphere of repulsion of the other: and for a like reason its antagonist evaporating force acts against it in every part of the liquid.

Cor. 4. The lower parts of the liquid are pressed by the gravity of the upper, and this part of the pressure is evidently the same in a close vessel, whether the whole above it be in the liquid form, or any portion of it converted into vapour.

Cor. 5. Hence the tendency to retain the liquid form will be something greater at greater distances below the surface.

Cor. 6. The evaporation will proceed from the surface, when the liquifying force is not less than the evaporating force.

Cor. 7. When the liquifying force, arising either from vapour or gas, is less than the evaporating force by a quantity sufficient to overcome the small effect of gravity or other circumstantial causes, the evaporation will proceed chiefly from the point or points of greatest heat, and when this is in the body, or lower parts of the liquid, it will produce ebullition, owing to the rising and escape of vapour. (31.)

Cor. 8. Liquids of the same kind, and in the same circumstances, will boil at the same temperature, when under a given pressure. (32.)

Cor. 9. Water and many other liquids will require a more elevated temperature to produce ebullition, when in a glass, than when in a metallic vessel.

This must always be the case in the vessel to which the heated atoms of the liquid adhere most firmly; for because of that greater adhesion of the atoms to the surface of the vessel, it will require a greater temperature (that is evaporating force) to produce vapour at the surface, where the greatest heat is applied, but on account of the greater heat the vapor will be formed there, and its ascent will raise the temperature of the liquid in the vessel; and of course the quantity of vapour due to that greater temperature, which will diminish the tendency to the formation of vapour in the body of the liquid, so that it will continue to be formed at the point of greatest heat, and the temperature for ebullition will be higher than in the vessel, whose surface adheres less to the liquid, yet from the given pressure at the surface there will be a tendency to reduce it to the same boiling point.

Cor. 10. When the liquid is boiled in a vessel, which raises the boiling point, the temperature of the liquid is much more fluctuating within certain limits, than in ordinary cases. (33).

This is a consequence from the last cor, since the rising vapour is of a higher temperature than that due to the extrication of vapour from the body of the liquid.

Cor. 11. If metallic filings, or cuttings, be put into the liquid in the glass vessel, the boiling point and steadiness of temperature will be, at least in a great measure, restored. (34.)

For the metal, lying at the surface where the heat is applied, will occasion the vapour to be formed and carried off as from a metallic vessel.

Cor. 12. The same will in some degree be effected by putting pounded glass in the vessel; for in this case the vapour will form also more freely at the angular points of the pounded glass. (35.)

Cor. 13. Under a less pressure, a liquid will boil at a lower temperature, as cor. 7. shews. (36.)

Cor. 14. If a liquid be confined in a close vessel, and the vapour be at a density due to the temperature, and that temperature be gradually raised, the liquid will not boil. (37.)

For in this case the liquifying force will increase in the same degree as the evaporating force.

Cor. 15. But if in the case of the last cor. a considerable part of the vapour be suddenly condensed, or suffered to escape, boiling will commence very rapidly.

Because in this case, vapour will be formed in every part of the liquid. (38.)

Cor. 16. All sorts of dry gases will absorb the same quantity of vapour, when exposed to liquids at a given temperature, (39.)

Def. 6. The true boiling point of a liquid, is the temperature which it has when exposed only to its own vapour, under a pressure of 30 inches of mercury.

PROPOSITION 21. *The boiling points will be different in the different sorts of liquids.*

For on account of the several sorts of atoms, and their various com binations in different liquids, there will be various degrees of cohesion of their particles, and therefore, they will require different liquifying forces, and hence (prop. 19, and prop. 20. cor. 7.) the boiling points will be different.

Cor. If substances be dissolved in a liquid, and be such as to increase the cohesion of the particles, the boiling point will be raised: this follows, because the liquifying force is increased by the cohesion. Thus solutions of potass, soda, common salt, &c. have a higher boiling point than pure water, and the vapour in consequence, although the very same in quality, is less in quantity at a given temperature. (40.)

PROPOSITION 22. *The liquid and vapour being as in the preceding propositions, if the temperature be raised by equal increments, through a moderate range; and if the numbers expressing the quantity of vapour, in a given space at each temperature, be divided by that at the next lower temperature ; there will be obtained a series of quotients, which in general will go on diminishing gradually, and successively by small quantities, as we ascend towards the higher temperatures.*

Were it not for the cohesion of the liquid, and other accidental circumstances, the liquifying, and consequently the evaporating force, when there is an equilibrium, would be as the pressure, or the density, or the quantity of vapour in a given space; and therefore, when the temperature is raised, the resistance to the evaporating force would be as the vapour present in the given space, and therefore the increment of vapour would be as the vapour present; hence for equal increments of temperature, the ratio of the vapour at the higher to that at the lower would be constant. But to the terms of this ratio must be added a quantity of vapour, such as would produce an effect equivalent to that of the cohesive force: now when the same quantity is added to the terms of a ratio of greater inequality, the ratio is diminished; hence when the temperature is increased by equal increments, the ratio of the vapour at the higher to that at the next lower temperature goes on diminishing. The cohesive force is nearly constant, but diminishes a little as the temperature is more elevated: hence the above mentioned ratio diminishes at a less rate in high than in low temperatures, both because the part due to the quantity of vapour is greater, and that due to the cohesion is somewhat less.

Some other causes will occasionally occur, affecting these conclusions, as when the liquid contains cohesive ingredients more volatile than the rest, or when it contains impurities not easily removed, or when it is affected by particular changes at certain temperatures, &c.; but generally within a moderate range of temperatures, the ratio will diminish gradually, as asserted in the proposition. (41.)

I shall add one proposition relating to the phenomena of freezing, or the conversion of water into the solid form.

Proposition 23. *When water is exposed to a temperature which goes on decreasing, its density increases, till it arrives at about 39° or 40° Farenheit; it then begins to expand, and the density continues to diminish, till the temperature is 32°, it then freezes, or becomes solid, if there be a slight agitation: but, if the liquid be kept perfectly still, it may be cooled down 8 or 10 degrees lower, before it loses its liquid form; and if in this case any point of the surface be gently touched, if only by the point of a pin, freezing commences immediately, and proceeds rapidly, the temperature rises to 32 , and the volume is increased about* $\frac{1}{8}$, *the ice has a crystalline form, in hexagonal prisms, the lines crossing in angles at 60° and 120°.*

The liquid being contained in a vessel open at the top, the atoms of water when at rest, will assume the position in fig 13, so that the two centres of hydrogen and the intermediate centre of oxygen shall be in a vertical line, as shown in the New Theory, also the atoms of electric fluid belonging to the atom of water will evidently be crowded about the oxygen as at *a* and *b*. Now as the temperature diminishes, caloric escapes at the surface between adjacent superficial atoms, situated side by side as above, and a general contraction ensues, which is greatest at the surface, where the caloric first escapes: now, as the temperature continues to decrease, the caloric rises, and escapes at the surface with greater difficulty, on account of the contraction there, and especially because of the electric atoms surrounding the oxygen, and which necessarily obstruct the passage: the rising caloric, which is prevented from escaping at the surface, tends to expand the strata of liquid below the surface, while it contracts at the surface, and the central parts; this portion of the liquid, which expands, increases as the temperature diminishes, so that at a certain term, the expansion in that part will equal the contraction in the other parts;

and this will be the point of greatest condensation, after which, the expansion exceeds the contraction, and the liquid on the whole dilates. At a certain point of temperature, if the superficial atoms be very slightly moved, any three contiguous atoms, coming together, will be retained in union by the action of the oxygen, and this will prevent the escape of caloric at the apex; hence it will find its way at the more easy path, between the lower atom of hydrogen and the upper one of the next lower row of atoms, this will swell the pores below, while, at the same time, it promotes a like arrangement in the surrounding atoms, and the whole is speedily frozen. But if the surface be preserved perfectly still, the caloric will continue to escape between all the superficial atoms, till the temperature is much lower than the freezing point; and if in these circumstances, the smallest part of the surface be touched, the apex of three atoms will be formed, and the caloric, which was rising there, will pass as above stated, and promote the immediate crystallization of the whole surface; the several pores below will be extended y the confined ethereal matter, while that which now escapes, at the new passages, will elevate the temperature, also the arrangement of the atoms of water in lines crossing at angles of 60° and 120° will be a necessary consequence, as shown in the New Theory of Physics, pp. 76, 77 and 78, where it is explained in what manner the hexaedral prisms are formed.

The preceding mathematical demonstrations depend simply on the two leading principles of the Theory, independently of experimental results. Is it not therefore, very remarkable that the above deductions from this very simple Theory, include nearly all those important facts, which the chemists have obtained by experiment, and denominated, Ultimate Facts? facts which have not received, and cannot receive any satisfactory explanation from the theories already sanctioned, except in some cases, by means of additional hypotheses invented for the purpose. Place for a moment some of these in review.

It is known as a matter of fact that gases flow into a vacuum, and also that they uniformly mix by diffusion, and in both cases with a velocity either exactly, or nearly in the inverse ratio of the square root of the density: these phenomena, it is allowed, are not referable to any received chemical principle, or provided for in the corpuscular philosophy of the day. But propositions 9 and 10, with the cors. show that they are equally the results of the theory as of experiment: the 4th and 6th props. are if possible still more remarkable in explaining facts which have not yielded to any other theory, especially Mariotte's law, which is also otherwise proved from the 19th proposition: likewise the conclusions in props. 11, 12, 13 and 14 are not, except on this theory, to be easily reconciled to known principles. Again it is a well ascertained fact, that the elements of bodies have peculiar electric relations, in accordance with which systematical arrangements of the elements have been made: it is also found that such arrangements are affected by change of temperature: and that, in given circumstances, a definite quantity of the electric fluid combines with given elements, which follows from the 15th prop, and its cors.; but no one will pretend to say, that they are explicable on any other admitted theory.

In chemical combinations the combining elements exist in very simple definite ratios, in respect both of weight and volume: and the resulting volume is always either one or two volumes, except in cohesive combinations, in which the volume is never altered: but the received doctrines, so far from explaining them, are certainly at variance with the facts themselves, and would lead to quite different conclusions, as was shown by Berthollet.

The relative weights of atoms have been determined very nearly by experiment in many cases, but scarcely any attention has been paid to the magnitudes of the spheres of repulsion, and indeed the inquiry would have been useless in the received crude notions of repulsion: the subject is difficult, yet by the help of the atomic weights, and props. 11, 12, 13, and 14, with other parts of the theory, we may frequently judge with great probability which of two given atoms has the greater sphere of repulsion.

Thus it seems very probable that nitrogen has a larger sphere of repulsion than that of any other element, as will appear from its considerable atomic weight, conjoined with its permanent gaseous form, the difficulty with which it enters into combination, the paucity of its compounds, their peculiar phenomena, and the explosive nature of many of them. On the other hand there are indications in phenomena, which would lead us to fix on carbon as having the least sphere of repulsion, or one among the least; this may be gathered from its absorbing light abundantly, its being solid, not only at common, but at very high temperatures, the nature of its combinations, its fixed nature when exposed to intense heat, and its property of conducting electricity.

Hydrogen of all the tenacious atoms has the least atomic weight, and, from its permanent gaseous form, its combining with but few elements, the gaseous form of most of its compounds, and other phenomena, we are compelled to admit that it has a large sphere of repulsion.

Reasoning from any received theory, we should be led to the inevitable conclusion that elements combine in all sorts of proportions, which is contrary to fact: but the theory before us indicates the fact itself, and shews that elements cannot be expected to unite in many different ratios, except in cohesive union, as we find on all occasions; cyanogen consists of one atom nitrogen and one carbon; it may indeed be asked, why cannot another atom of carbon combine with cyanogen: it may certainly combine with it, but, the additional atom of carbon could not remain at any part of the surface of the nitrogen at a distance from the previously united atom of carbon, and when it is brought near it, whether it will continue in combination or be separated will depend on the relations of the atomic weights, and spheres of repulsion: and had we room we might shew good reasons for the number of combinations which are observed in the majority of cases. The relations of carbon and hydrogen in respect to their spheres of repulsion, as above noticed, lead us to anticipate, that from their union will arise many diversified compounds, and even isomeric results, of which several are known, even as matters of fact: hence we may foresee, that these, with some element, such as oxygen for instance, suited in its weight and

sphere of repulsion to combine with them, are adapted to produce that immense and pleasing variety, which is presented at every point in the vegetable kingdom; at once administering sustenance and pleasure: at the same time, nitrogen presents manifest signs to shew that it was formed to constitute the basis of the terrestrial atmosphere, so necessary for the continuance and comfort of life.

Isomeric and isomorphous compounds will doubtless become important in tracing the properties of bodies from their elements: I need not say that the received theories leave us in the dark respecting such investigations and facts, while the facts themselves are antecedently indicated by the new theory. Olefiant gas, etherine, methylene, and oil gas, (Nos. 14, 19, 37, and 62) are isomeric, the existence of one of these, methylene, I had concluded to be exceedingly probable, before I knew that the compound was discovered; various other cases will present themselves to the studious reader. The remarkable uniformity of the four compounds of phosphorus and arsenic with hydrogen in Nos. 47, 48, 49, and 50, tend to illustrate the isomorphism of the two elements.

In conclusion, permit me to solicit attention to two or three particulars, in reference to the table at proposition 17th; and 1st: alcohol and protohydrate of methylene, have the same elements, and vapour of the same specific gravity, and yet are different substances; each contains nine atoms, viz. six hydrogen, two carbon, and one oxygen; two volumes exactly when compounded, but nine volumes in a separate state: now let me inquire what other theory can shew why the nine volumes should be contracted exactly into two, or that this could be effected two different ways; that they may be composed in a different manner is easy to conceive, but that the specific gravity should be the same, is altogether gratuitous, except from the theory before us, which shews how they may be composed, as the facts indicate, and that the specific gravity must be either the same, or one double of the other, and that the nine volumes must become either one volume or two exactly. Again, six volumes, or six atoms, viz. two of carbon and four of hydrogen, make exactly one of etherine; also thirteen volumes, or thirteen atoms, viz. five of carbon and eight of hydrogen, make exactly one volume of camphene: now what other theory could possibly lead to this result? we cannot reduce six solids to the space of one, or thirteen to the space of one, though we may well allow of some contraction; yet why a contraction to one volume exactly? And yet unlikely as all our previously conceived notions would lead us to expect this, it is a result which our theory not only suggests, but predicts with certainty. A little attention to the table will shew that the combinations in the most complex cases are similar to those in the most simple; thus, precisely in the same way that two atoms of hydrogen connected by one of oxygen form water; two atoms of olefiant gas connected by one of water will form one of the two, alcohol or protohydrate of methylene; and one of etherine connected with one of water cohesively, as muriatic acid is formed, will form the other; most probably the protohydrate: yet the theory will admit of a different manner of combination, producing the same result without the fraction of a volume; it is for experiment to decide which is the true order and manner in which the elements combine, and this, by the help of the theory, it can very frequently do: similarly two atoms of etherine, connected by one of water, will form ether, in all fifteen volumes contracted into two exactly, just in the same manner that three volumes are contracted into two in any of the compounds from number 28 to 43 inclusively; thus a very puzzling knot in chemical composition is untied.

These and many such remarkable and unlikely coincidences of theory and experiment, cannot be accidental; I will leave the propositions relating to evaporation to speak for themselves: but such exact agreements cannot result from chance, nor from any received theories: how is it possible if the atoms of matter be solids in juxta position, whether they are spheres or spheroids, or other figures: the results of experiment never can be accounted for on such principles; and equally remote from just explanations is the doctrine of alternate spheres of attraction and repulsion, or that of electric energies, or any other, but the one before us: even crystallization fails to be explained by solid spheres, and spheroids, with all the patchwork of poles, and rotations, and revolutions, &c. while our theory presents the whole subject in the clearest and most simple light imaginable, according to this theory crystallization will become intelligible, and a mathematical science.

We cannot now pursue this subject in detail, or extend our contemplations in this almost boundless field, teeming with the richest productions: but we may be allowed to state that every element has its general and particular use; thus each and all are proportioned and ordered and adjusted, so that the most perfect harmony and concord, is every where observed, and the several individuals, complete in themselves, and in their more immediate connections, contribute to form one entire and general result of usefulness and elegance: one world, one universe, equally attended to and regulated as one atom, and one atom equally as one universe. We are not then to suppose that the atomic weights or the radii of the spheres of repulsion of atoms are exact multiples of any one of them, or even that they are commensurable quantities: the Creator does not, in His Mathematics, if men may thus speak, confine Himself to whole numbers, straight lines, circles; &c. but in the minutest parts, He has had special regard to perfection in the accomplishment of his majestic, extensive, and benevolent operations.

It may be observed, that the figures in parentheses are intended to denote the most remarkable phenomena which have been established by experiment and observation as ultimate facts, never before explained on any general theory, other results not so distinguished will be seen in the appendix.

APPENDIX,

CONTAINING THE

Application of the Theory to Electricity, and Magnetism, with

OBSERVATIONS ON COMETS.

While writing the "New Theory of Physics," it was my lot to clear in some degree new ground for cultivation, and being quite single handed, it was not to be expected that the best possible explanations of phenomena should be given in the first essay, and hence it was stated in the work, that some of the explanations were simply intended to show a general correspondence between the theory and the facts: and I do not find that any philosopher has been able to show a single fact, in the whole compass of natural effects, which is in any degree subversive of the theory, or of the general deductions, which it presents. But of the immense number of facts brought forward in that treatise, by far the major part, and those the most important, will be found to be clearly explained, while, at the same time, it will be allowed, that as the theory becomes more completely developed, the explanations may be still more clearly exhibited; the admission that the electric fluid holds its rank as a separate class of atoms, between those denominated tenacious and ethereal, will offer great advantages in this respect, and such a distinction is plainly allowable on the principles of the theory.

It is my purpose in this appendix to give improved explanations of the leading phenomena in electricity, galvanism, and magnetism on these grounds, as well as of some phenomena of comets.

In electricity it will suffice to consider, 1st. The conducting or transmitting power of bodies. 2nd. The excitation of electricity. 3rd. Its accumulation. And 4th. Electrical attraction and repulsion.

I. It is well known, that some bodies transmit the electric fluid with great facility, others scarcely allow it to pass at all; and bodies of every intermediate degree of conducting power are found in nature: the following are a few selected for example, and arranged in the order of their conducting power. Metals, charcoal, water, earths, pounded glass, oxides, baked wood, dry gases, glass, resins, shell lac.

This property, discovered by Mr. Grey, in 1729, lies at the foundation of electrical science, or rather it is the foundation stone, and no electrical theory which leaves it unexplained can be a good one; it is however very remarkable, that no satisfactory step has been made towards this point: I have consulted nearly one hundred authors, most of whom are quite silent respecting the cause, and the others do not attempt a solution. Dr. Priestley asks, "in what does the difference between conductors and non-conductors consist?" Biot, who generally investigates accurately and deeply, merely says, that the air retains the electric fluid on bodies, because in vacuo it is dissipated. Mr. Lunn has the same remarks. Mr Nicholson thinks the conducting power is increased by increase of temperature, but Sir H. Davy established the general fact, that metals are worse conductors at higher than at lower temperatures. Dr. Young says, perhaps the conducting power depends on oxidation, perhaps on affinity. Mr. G. Adams observes, "the cause is among electrical desiderata." Mr. Singer says, that "there does not appear to be any definite relation between the chemical characters of bodies and their conducting powers." "Nor does it appear that specific gravity, hardness, tenacity, or crystalline arrangement of particles, are connected with the power of electrical transmission."

In the absence of every probability of an explanation according to the received principles, let the new principles be applied, and in order to this, we will first suppose a case, in which let M, N, O, &c. fig. 20 be a line of atoms fixed in their places, and the relations of their absolute forces, and the radii of their spheres of repulsion such, that they may attach to their surfaces of repulsion a great quantity of electric atoms, which by prop. 2. case 5. will occupy the lowest strata of the atmospherules, and will be attached firmly and closely to the tenacious atoms, and these being in a state of equilibrium with the surrounding air, and other bodies, will neither give, nor receive electric fluid. Now let electric fluid be communicated to the adjacent body A, by small quantities at a time. The electric atoms and ethereal matter, constituting the atmospherule of M, will oppose a resistance to the passage of electric fluid from A to M, and this resistance will be the greater as the electric part of the atmospherule of M is the more closely and firmly attached to it, and is more distinct and separate. But after a certain quantity of electric fluid has been communicated to A, the resistance will be so overcome, that a body of electric atoms will pass from A to M, producing a repulsion between A and M: and now the transmitted atoms will be attached to M, and will increase the resistance to the passage of additional electric atoms. In this case the transmission of electric fluid will be arrested, but the atmospherules of all the atoms M, N, O, &c. will be pressed, and extended towards the opposite side. If again electric atoms be communicated to A, till some are again transmitted to M, and in such quantity that a very small portion may pass to N; then at this stage, the advance of electric fluid will be arrested at N, similarly the electric fluid will advance from atom to atom by steps, in succession as it is communicated successively to A: consequently the intensity of the electricity on A being given, the body composed of the row of atoms M, N, O, &c. will permit the electric fluid to pass only to a given distance, more or less, according to the distinctness, and closeness of attachment of the electric atoms on the tenacious atoms of the body. This body will be a very good non-conductor, when the relations of the atoms of the body, to those of the electric fluid, are such, that each shall retain it in a large quantity (see prop. 15.) but when those relations are such, that the electric atoms scarcely at all attach themselves to the tenacious atoms of the body, then as fast nearly as the electric atoms pass from A to M, they are propagated over the whole body M, N, O, &c, by their elastic force, that is by their mutual repulsions, which operate freely when not affected by the actions of the tenacious atoms, since their centres are within the sphere of each other's repulsion, so that they separate with great force. This body will be a good conductor. It is easy to see, that in nature we should expect to find bodies of almost every other degree of conducting power, between very wide extremes, and that no other conditions are necessary to make the distinctions in the conducting properties, than those above stated. The body in order to be a good non-conductor must contain tenacious atoms, whose absolute force and spheres of repulsion are so related, that they shall retain a large quantity of electric atoms, and in compound bodies, these atoms must be so exposed, that the electric fluid can have access to them readily. How exactly all this is in consonance with nature, let the electrician decide.

II. These observations respecting the conducting power of bodies, will apply in explaining excitation. Excitation by induction is produced thus, let the line of atoms A B be a good conductor, and let an excited body be placed near it, but not so near as to give a spark. Then in consequence of the excited body, the electric fluid of the atoms of the surrounding air will be extended from or towards the excited body, according as it is positive or negative, and the atoms of air, thus affected, adjacent to the end A of AB, will affect the fluid on the surface of that conductor, without either giving or receiving any of the fluid; hence the electric fluid of A B will be moved from the end A, towards B, or from B to A, according as the excited body is positive or negative. All this is evident from the conducting power of bodies.

If the excited body be placed nearer to, or in contact with A B, a portion of fluid will pass between A and the excited body, which being removed will leave A B positive or negative.

When two very dissimilar conductors are placed in contact, their actions on each other, and especially their different actions on the ethereal, and electric atoms, and other matter between them, will produce a difference of electrical state, and hence an excitation of the bodies by contact.

This will be much more intimate and complete, when bodies are briskly rubbed together, in consequence of the renewal of the surface in contact; and hence excitation by friction.

Excitation by chemical action, evaporation, and other natural processes is easily explained on the same principles.

III. What was advanced on the first head, will also serve to explain the accumulation of the electric fluid on bodies, in a complete and most satisfactory manner. Thus let M S, fig. 20, be the transverse section of a thin piece of glass magnified; A and B parts of metallic coatings, let A be in contact with a positive prime conductor, kept at a given intensity, and B insulated. Then, as explained in part I, the fluid from A will be transmitted through several atoms M, N, &c. of the thickness, as suppose to P, and the rest as from P to S will have the electric fluid extended to the opposite sides towards B, and the fluid belonging to B will extend outwards ready to pass off to any uninsulated conductor presented to its surface, and this is the state of all the atoms of the glass in contact with the coating. Now let the uninsulated conductor be presented to B, a spark will pass to it from the coating, and this will lessen the resistance to the extension of the fluid on the atoms of the glass towards the coating B, hence, since the intensity of the electrical state of the prime conductor is given, a spark will pass from the coating A, and from A to M, N, &c. so that now it may pass as far as Q, and for the same reason another spark can be taken from B, consequently, another will pass from A as before, and so on, as often as a spark can be taken from B, one can be given to A, till the greatest difference between the electric state of A and B, which the electrical intensity of the prime conductor can effect, is produced, and then the plate is said to be charged.

If now the charged plate be removed from the charging conductor, the pressure of its fluid on A being taken off, the electric fluid of the coating A will extend outward, tending to escape, and that on B will consequently extend inward, so that now it tends to receive electric fluid, from contiguous bodies especially conductors, that is, A is positive and B negative. If under these circumstances a conductor, communicating with one coating, be brought also into contact with the other, a quantity of fluid will rush along it, from A to B, restoring the equilibrium at these coatings, and the contiguous strata of the atoms of the glass plate, but not perfectly at once on the interior strata, this, the connecting conductor being removed, will be slowly restored in part, causing the accumulated fluid to pass towards the coating A, to extend outwards, and from B inward, and this forms what is usually called the residual charge.

Nothing can more naturally or completely explain these beautiful and interesting phenomena, at the same time setting aside all the noise and nonsense which has arisen about the permeability of glass to the electric fluid. It shews also why thick glass will not take a charge to any considerable amount from a prime conductor of low intensity, while the same conductor would give a good charge to very thin glass, and the thick glass itself would take a strong charge from a prime conductor of high intensity.

We may observe that if the coating A had been connected with a negative prime conductor, the reverse process would have been effected, B would have received electric fluid from uninsulated conductors, and A would have given off its fluid to the prime conductor, and at the close, the plate would be charged positively on the side B, and negatively on the side A, and the fluid would be carried from B to A in the discharge.

IV. But the same explanation of conducting power will also apply to electrical attraction and repulsion. In treating of non-conductors, the transfer of electric fluid from A to M, and thence to N, &c. was noticed; now when an atom of electric fluid passes from M to N, if these tenacious atoms M and N were at liberty to move, M would go towards A, and N towards B; for since the electric atom moves through a dense body of ethereal matter, when it leaves its place, accompanied by its own atmospherule of ethereal matter, going from M to N, the surrounding ethereal matter rushes into the place it leaves, producing an action recurring through the whole line of its motion, and evidently this action tends to accelerate its motion, and reacts against M, causing it to recede

in the opposite direction. On the other hand, in passing to N, the electric atom, with its atmospherule, has to remove the ethereal matter in the line of its passage, which acts as a retarding force, and produces a reaction on N, tending to propel N towards B; hence on both accounts M and N recede, when at liberty, from each other, and this is a case of electrical repulsion. If no electrical atoms pass between N and O, and especially if while electric atoms pass to N from the side A, and to O from the side B, N and O will approach each other, which is a case of electrical attraction.

Let A and B, fig. 19, be two light bodies, as pith balls, suspended so has to move freely; and 1st, when they are both positive, let *e* and *c* be atoms of air contiguous to one of them, as A: now the tendency of the electric fluid to escape from A and B will cause the atmospherules of the atoms *e* and *c*, with others near them, to extend outward from A and B, as shewn in part first; and as represented in the figure by the lines from the centre: the joint effect of these actions will be to extend, or protrude the electric fluid in directions, passing through points *n* in A B, between A and B, as represented by the lines with arrow heads at *e*, *c*, &c. Also by these actions the electric fluid will be propelled towards the exterior side *q*; and the greatest intensity will be on the side between the balls; hence the electric fluid which escapes into the air from the ball A, will pass off on that side: the same reasoning applies to the actions of the two balls in respect of the fluid on B: but the passage of every atom of electric fluid from A and B, to the atoms of air, causes a repulsion between them, as shewn above; and since this takes place on both balls, on the sides between them, a repulsion between the balls will be produced, and this is augmented by the passage of the electric atoms from one atom of air to another, or to any conducting substance present: hence a separating action is produced, removing the balls to a distance depending on their weight, and on the intensity of the electricity. But besides the above there is another very important concurring cause, which was overlooked in the former explanations of electrical action: it was stated above that part of the electric fluid of the balls is, in the case before us, propelled to the exterior surfaces, as toward *p* and *q*, but this is performed by the atoms of the electric fluid passing from atom to atom on the surface of the balls, as from *a* to *b*, and *r* to *s*; now in leaving *a* a repulsive action, as in other cases, is produced, and the result of this action on the ball, and the atoms contiguous to it, as well as on the adjacent ethereal matter, will be in a direction *h a*, proceeding from some point *h* between A and B, and the same electric atom entering the atom *b* will have its resultant action also in the same direction very nearly; the same may be applied to the corresponding points of the surface *r*, *s*, and at every similar point on the surface of the ball: the same reasoning applies to the ball A; hence these actions produce a repulsion, even if no atoms of the electric fluid permanently leave the balls. The same conclusion holds good respecting any electric atom which passes from *k* to *l*, or from *t* to *u*, and the resulting action, as indicated by the arrow head at *c*, is in a direction from some point, as *n*, between the balls, both in going off from one atom, and in entering the next atom of the surface. If the electric atom should return, and pass from *b* to *a*, or from *l* to *k*, the action would be precisely the same, and in the same direction: hence every motion of the electric fluid, on the surface of the balls, produces a repulsion between them, keeping them at a certain distance dependent on the intensity of the electricity, and the weight of the balls.

2nd. It is evident from this explanation, that if both the balls were negative the same repulsion would be produced, the only difference in the two cases is, that the motions of the electric atoms in one case are exactly opposite to that which they have in the other; but the effect with regard to the repulsion is precisely the same, whether the motion be in one direction, or in its opposite, when passing between two atoms of the body, or of the surrounding medium.

3rd. If one ball be positive and the other negative in an equal degree: then it is easily seen, by reasoning as above, that the electric atmospherules will be protruded in lines drawn from the produced parts of the line A B, in the small angle of the intersecting lines Ae, Be, at the side between them, and in the greater angles of Ac, Bc, on the farther sides. Therefore according to the above conclusions, every action arising from the passage of the electric atoms, whether from the balls to the atoms of the air, or from one atom of the air to another, or from one atom of the surface of the balls to another, will be an action on the exterior opposite sides of the balls, as at *p* and *q*, propelling them towards each other, and thus producing electrical attraction.

4th. When one ball is electrical, and the other in its natural state; or one very strongly electrical, and the other only so in a very small degree, electrical attraction will be the consequence, as will easily appear from considering the circumstances of the case in connection with what has been advanced.

Thus we see that the varied electrical phenomena of, 1st, conducting power, 2nd, excitation, 3rd, accumulation of the fluid, and 4th, electrical attraction and repulsion, depend entirely and exclusively, on the same principles, and to these all electrical phenomena whatever are referable.

The phenomena of two electrical fluids was invented chiefly to account for electrical attractions and repulsions, and it has been asserted with more plausibility than reason, "that the sole enunciation of the hypothesis seems to be an abridged explication of the phenomena." But even the best explications given on this hypothesis are not so complete as some have imagined: for cases may be shewn, in which two bodies, both positive, or both negative, shall attract each other, which is quite in opposition to the theory.

This is shewn by the following experiment: A and B, (fig. 19) are pith balls, suspended by non-conductors, as by glass drawn to very slender rods: a small common needle was stuck on the exterior side *q*, of the ball A, with the point outward; another was similarly placed on B at *p*: these balls, being equally electrified, either from the positive or negative prime conductor, attract each other, which is contrary to what ought to take place on the hypothesis of two fluids—but it was actually predicted from the "New Theory."

Another case may be adduced, where points are not concerned: coat with tin foil, each of two flat even surfaces of window glass on one

side only, and to within about an inch and a half of the edge: charge each positively on the coated side, and consequently each negatively on the other side: place the uncoated sides in contact, and they will cohere with great force. According to the theory of two fluids, they ought to have repelled each other; but it was a predicted result of the New Theory, that they should attract. The same adhesion takes place when both the uncoated sides are positive, and placed on each other; these simple facts, and the doctrine of two fluids can never be reconciled.

In respect to Galvanism, an important branch of electricity, it will be sufficient here to shew the general principle, by means of a simple case, easily verified. Into a wine glass pour a solution of nitrate of copper (if no solution be at hand, it is easily procured, by dissolving a little copper in nitrous or nitric acid diluted with two or three parts water); dip a clean piece of iron wire into the solution, a portion of its surface will be dissolved, and copper deposited in its place; but no action would be produced on a clean common pin, similarly dipped in the solution. If both are introduced at the same time, but unconnected, the iron is acted on as before, and the pin is unaffected. Now put the upper ends of the wire and pin in close contact, and dip the other ends, being a little apart, into the solution; the wire is acted on more than in the former case, and the pin becomes coated with copper, but most on that side nearest the iron.

The following explanation deduced from the theory may be considered as applying generally to all similar phenomena. It was shewn (prop. 16) that bodies combine in proportions definite and simple, as to weight, and that bodies of one class will combine to the exclusion of those of another (prop. 16, cor.), nitrate of copper is an instance: a coat of oxide of iron is formed on the surface of the wire at the expense of the oxygen of a portion of water in the solution, its hydrogen escaping in the gaseous form; this oxide requires in its composition a supply of electric atoms, which are derived from the best adjacent conductor, that is from the interior of the wire, leaving its interior and upper part negative, and from the non-conducting property of the oxide, it maintains for some time a given difference of intensity, between the wire and the liquid. Now when an atom of the nitrate of copper is applied by juxta-position to the oxide of iron, its acid combines with the oxide of iron, to the exclusion of the oxide of copper, which is propelled to the wire, and the nitrate of iron from it, by the transfer of ethereal and electric matter between them, as always happens when such transfers occur; another portion of oxide of iron is formed in place of that removed, at the expense of the oxygen of the oxide of copper, and of the water, for what more may be required, and the copper is precipitated: hence, while this process continues, there is a tendency to draw electric fluid from the interior of the wire. No such action takes place with the pin alone, because the tin does not decompose the water, the acid of the nitrate of copper will not combine with the tin in these circumstances. Let now the upper parts of the wire and pin be in close contact, while the other ends are immersed; and the interior of the wire, its upper part, and the pin are, as seen from what is said, in a negative electric state in respect of the immersed surface of the iron wire, and the contiguous liquid;

hence electric fluid from the liquid will enter the pin, since it is a good conductor, and this adminsters to the surface of the wire, a supply of electric fluid, and the action is consequently increased, whilst the removed oxide carries a portion of the electric fluid to the water, and the formation of the oxide continues to draw electric fluid from the interior of the wire, and consequently from its upper part, and from the pin: thus, as long as the chemical action continues, a current of electric fluid is produced, and continued from the surface of the wire where it originates through the water, the pin, and the interior of the wire to its surface: and this is a simple galvanic circle, to which every single circle is similar. It remains to shew why the pin is now coated with copper.

When an atom of the copper is freed from its combination, in the process of decomposition, it still adheres to the adjacent atom of oxygen, or water, or other adjacent body in the electric current; now of the two atoms so adhering in the current, that to which the electric fluid most easily attaches itself will be turned towards the source of the current, and that which most easily transmits it, or is the best conductor, will necessarily be brought by the current to the opposite side, facing the body towards which the current flows: therefore the electric atoms passing in the medium from atom to atom, when the best electric, that is in this case the oxygen, or the water, is saturated with electric atoms, a portion of them will pass off and enter the adjacent, or adhering atom which is a conductor, in this case the copper: hence, as in the common cases of electrical repulsion, the atom of oxygen, or water will be propelled towards the source of the current, that is here towards the iron wire, and the copper in the opposite direction, or with the current, towards the pin: the same process will take place at the next atom to which the copper becomes attached, and thus, at whatever part of the current the copper is found, it will be propelled towards the pin, till it reaches its surface, and is then propelled close to the surface, while the electric fluid thus carried to the pin, is conveyed through the pin to the wire as above explained, leaving the copper firmly adhering to the surface of the pin. Many atoms of copper are thus simultaneously advancing towards the pin, and several at the same time attaching themselves to its surface: hence the side of the pin which faces the iron wire soon becomes coated with copper, and the other sides in succession, so that on withdrawing it, at a proper interval, it is found to be coated all round, but the copper is laid on much thicker on the side nearest to the iron. It is easily seen how the electric fluid tends to separate the elements of bodies, either where it leaves the iron, or where it enters the other metal; and this will be more effectual when the current leaves or enters a point of a conducting body. This particular case is an exemplification of decomposition and transfer by galvanism in general. We may observe here, that the intensity of the electricity depends on the electric atoms required to supply the newly formed oxide, and on the relative non-conducting power of that oxide; and the quantity of electricity, produced in the current, will depend on the quantity of surface of metal exposed to the chemical action of the liquid, and also on the rapidity of that action, by which the coating of oxide on the iron is more or less frequently renewed. Thus it is seen, that the whole

of these beautiful phenomena of decomposition and transfer, are neither more nor less than the operations we have noticed in common electricity, carried on under particular circumstances; nor can these effects, here so simply explained, be explained in any other way, unless by hypotheses invented for that purpose. The above experiment was chosen on account of its simplicity, since any person may easily verify it, but a silver wire, instead of the pin would be still more satisfactory.

A compound galvanic circle will now be easily understood. In any number of wine glasses pour a little of the solution of nitrate of copper, and procure as many pieces of iron wire as there are glasses, and an equal number of silver wires; twist one end of each iron wire to the top of each silver wire, making as many pairs as there are glasses, and immerse the other ends into the glasses, so that the twisted part may not be in the liquid, and the iron in one glass, and the silver end in the next, placing the several pairs in the same order, so that in each glass there is an iron, and a silver wire, not in contact; this forms a compound galvanic circle; all the iron wires will be acted on, and all the silver wires will be coated with copper. Those who cannot conveniently procure the silver wire, may substitute clean common pins, twisting the iron wire just under the head, and not suffering this part to be immersed in the liquid.

Take any of the glasses as the first, and the rest in order, proceeding from the silver to its connected iron; remove the pair of wires which connect the last and first glasses; then, as shewn above, the action of the liquid of the second glass on the iron will draw electric fluid from the interior, and upper part of the iron wire in it, and consequently from the silver of the first glass, leaving the second glass in an electrical state somewhat higher than the first, and maintaining a given difference of intensity, depending on the quantity of electricity required to supply the oxide newly formed on a given part of the surface of the iron wire: and this affords a quantity of electricity to the liquid of the second glass, depending on the quantity of iron surface immersed, and the energy of the chemical action: for the same reason the third glass will maintain the same given electrical intensity above the second, that the second does above the first; and the same will hold in respect of the fourth, fifth, &c. glasses, to the last; and the intensity of the last will be as the number of pairs producing the action. If now the first and last glasses be connected by the removed pair of metals in the same order, the compound galvanic circle will be formed, and an electrical current established through the apparatus. This example contains the principle, and is a representative of what takes place in every compound galvanic circle, *mutatis mutandis*. If in this compound circle, for the purpose of interposing bodies for experiment, a break be made between the silver and iron of two adjacent pairs of wire, the end next the iron will be positive and the silver end negative: but if the break be made between the silver and iron of the same pair, the silver end is positive and the iron negative: this has introduced some confusion with some authors respecting the distinction of the negative and positive ends of the galvanic circle.

The explanations of magnetic phenomena, given in the New Theory of Physics, has always afforded me the greatest satisfaction, because

I am persuaded, that there is no fact in Magnetism, whether in what is called natural, artificial, or terrestrial, but will admit a most satisfactory explanation according to my general principles, and in the same way as exhibited in electricity, and the same will also apply to every phenomenon in Electro-Magnetism.

In corroboration of this, two or three observations, and statements may be added to what is advanced in the New Theory, in which it was shewn beyond the power of contradiction, that a current of ethereal matter, including the electric fluid, is continually rising in the equatorial regions to the upper parts of the atmosphere, and probably very much higher than the common atmosphere of tenacious matter, and that this fluid gyrates round the earth from east to west in spiral curves, winding from the torrid zone towards the arctic and antarctic regions, at the same time in high latitudes descending and entering the earth. Besides the reasons given in the treatise above referred to, an additional cause for the extrication of electric fluid from the earth and sea in the equatorial regions, and its elevation there, is the immense quantity of vapour raised continually in these hot climates: for it is a known fact that vapour carries off electric fluid from the body which yields the vapour, and when the vapour condenses, it gives out its additional electricity. It was shewn that the gyrating current is checked and condensed in its progress towards the poles, by the dry and cold air in the polar regions, so that near, or within the arctic circle, in an irregular zone parallel to the equator, the electric fluid enters the earth most copiously, a circumstance giving rise to the aurora borealis; and that at some point, or points, in this irregular zone, the electric fluid enters the earth with more freedom, and in greater quantity, than at the other parts: such a space in this zone is the terrestrial magnetic pole; this was concluded from theory, without knowing from any well attested fact, that the electric fluid will pass to, or from a conductor more freely at the place where it has already found a passage, than at other parts of that conductor; but since that work was published I have found it true in common electricity. Having fitted up a large machine, the cylinder, and the two conductors being supported by glass pillars, I found that it acted so powerfully as to give a spark at the distance of about eight inches; the conductors were made of tinned plate, covered with black japan. Several times while making experiments, when the machine was in full action, I held my hand at three or four inches from the negative conductor, and found to my surprise that no spark would pass, while a little before, and a little after, it would pass at the distance of about eight inches; my son equally noticed this peculiarity, and we several times examined the apparatus to ascertain if possible the cause: at length it was found, that, by putting my hand to the distance of one or two inches, a spark would pass, and then by drawing it back gradually, the spark would continue to pass, till the hand was removed to the distance of seven or eight inches. This is a decisive proof, that the electric spark will pass through a portion of air much more freely, and to a greater distance, after it has begun to pass there, than if it had not obtained a passage through it previously.

This confirms and establishes the conclusion, that the gyrating electric matter enters the earth most copiously at some point or points in the irregular zone above noticed: and this circumstance will affect the motion of the gyrating electric atoms, diverting their course so as to make them move round the centre of the space where they enter the earth most freely, towards which space, or terrestrial magnetic pole, the needle will be directed, as shewn in the "New Theory of Physics." Now this pole cannot be stationary, because the conducting power of the air is greatly affected by changes of heat and cold; hence the needle will have diurnal and annual oscillations, but on the whole it will advance westward, because that is the direction of the general current of ethereal matter, which will necessarily tend to carry the point of entrance forward in the direction of its motion, that is westward. But this motion westward will not be uniform, because in the zone in which it advances, some parts of the earth conduct electricity better than others, and it is for this reason also that the zone is itself irregular, sometimes a little nearer to the pole of the earth, and sometimes a little more remote: also the nature of the soil, and the earth, with regard to minerals, and conducting substances between a given place and the magnetic pole will affect the direction of the current, and consequently of the needle at that place; so that the magnetic pole will not seem to advance at the same rate, if calculated from two places, even when these places are not very far distant, as suppose London and Paris: these observations with what is stated in the treatise being compared with the absolute facts, leave it beyond the shadow of a doubt, that this is the true cause of magnetism.

There is a remarkable phenomenon respecting the Aurora Borealis, utterly inexplicable, except on these principles; and this is its more frequent appearance during some periods of years than others, which difference our theory leads us to predict from the greater difficulty with which the electric gyrating matter enters the earth at some places in the motion of its pole westward, than at others: see the explanation of the Auroa Borealis in the work to which reference has been made. The Aurora generally agitates the needle, and Cassini shews from observation, that it sometimes produces a permanent change of direction, all of which are obvious conclusions from the theory as well as from facts.

The manner in which magnetism is induced in bodies is also manifest from the theory, by considering the difference of the conducting power of bodies, and the reason of that difference, as shewn above in the section on electricity. All metals are good conductors, but they are so in different degrees; also the manner in which the electric atoms are conveyed by conductors must be regarded: the electric atoms with their atmospherules being by the pressure of the medium in which they are contained, compressed so as to have their centres within each other's spheres of repulsion; when a body of them escapes through a portion of air, and enters the metal, not being retained with much force on the atoms of the metal, as shewn in the part on electricity, they will by their elasticity, that is by the repulsion, which tends to separate them, be conducted through the exterior atoms which compose the surface of the metal to a very small depth, from one atom to another of that surface, and within, as well as in the adjoining medium, contigious to the surface; besides in this motion the electric atoms will be continually rising from the metal into the adjoining medium at some of its superficial atoms, and re-entering at the next, so that the current of electricity along the metal will be a kind of undulatory current; also from what was shewn always to happen in the transfer of electricity, there will be a repulsion between the atoms of the metal, and of the electric atoms leaving its surface, and also between them and the metal, when they re-enter; hence there is a repulsion acting constantly, and equally on all sides of the metal, between it and the electric atoms, through its whole length, so long as the current continues. Now in order to know the conditions in reference to the metal, necessary to its being capable of magnetism, we must observe, that if the particles of the metal be so fixed, that the electric current, passing through and among them, produces no change of position or arrangement, magnetism cannot be induced in the metal; on the other hand, if the particles have their positions changed with very great ease and freedom, no magnetism can be produced in the body: but when the moving electric atoms can produce a change of position in the superficial atoms of the metal, and if at the same time that position can be retained with a moderate degree of firmness, the body will be capable of permanent magnetism; this medium condition is not likely to appertain to many conductors, but it appears to belong to iron, cobalt, and nickel; hardened steel is found to be the most general and suitable substance for this purpose: that the atoms of tempered steel firmly retain the positions given to them, is manifest from what we observe in edge tools, which are easily made sharp and retain their edge; soft iron easily acquires the proper position of its superficial atoms, but retains that position with but a small force. To exemplify this, let a long soft iron rod be placed in a position nearly vertical in some high northern latitude; now while the electric fluid tends to descend along the rod, being a conductor, the gyrating current will pass by the sides of the rod from the east, westward; and because that current is advancing northward it will make the deepest impression on the south side; the effects of this, combined with the tendency of the fluid to pass downward, will be to produce a channelled course spirally round the rod from the top to the bottom, and the superficial atoms of iron retaining their new positions, with a moderately small degree of force the rod will be, while in this position, a magnet, the electric fluid passing down in a spiral course round the rod from east to west, on the south side, consequently towards the north on the west side, &c. The theory indicates that if the rod had been placed vertically in a high south latitude, the fluid would descend similarly, going down westward on the north side, &c. The former of these I called a north, and the latter a south magnet.

An easy mode of distinguishing and recollecting the course of the currents in these two kinds of magnets, is to suppose the fore finger of the left hand to represent a north magnet, and that of the right hand a south magnet, the current entering at the lower joint descending between finger and thumb, and so passing round rising between the fore and second fingers in a spiral, leaving the finger at the tip, which on the left hand is the north pole, and on the right hand the south pole. Either of these may be made to represent a magnet of the same kind as the other, by merely supposing the spirals to flow in a contrary direction, that is still to enter at the joint, but to rise between the thumb and finger, and to descend between the fingers. It is therefore easy to conceive, and to view the course of the current in two magnets of the same, or of different kinds, and placed in continuation as one line, either with like or unlike poles in contact. If these observations be fixed in the mind, all the peculiarities of magnetic and electro-magnetic attractions and repulsions, and the consequent motions, may be apprehended, and conveniently illustrated; it is seen that the current supposed on the finger is in a direction nearly perpendicular to its length. If now the rod of soft iron be removed from its vertical position, it loses its magnetism in a short time, because its fibres, or superficial atoms do not retain their new positions with firmness sufficient to resist the new impressions of the fluid acting on it in a different direction. But if while the rod is in the vertical position, a sewing needle, or other slender piece of hardened steel, be placed at either end of the rod in contact, and in the direction of its length, and be allowed to remain there a considerable time, it will become a permanent magnet; for in the hardened steel the arrangement of the superficial atoms, requisite for magnetism, is with greater difficulty attained, but after it is once effected, the position of the atoms is more firmly supported, and the electric fluid will flow in the paths or spiral channels previously cut in the surface of the steel more readily than in any other course. The lower end of the needle while in contact with the rod is its north pole; if such a needle be in an electric current, and at liberty to take any direction, it will place itself at right angles to the direction of that current, since it thus flows across the magnet.

Every method of producing magnetism in any body, whether by terrestrial magnetism, by a natural or artificial magnet, electrical action in various ways, or by vibratory motions in an electric current, or by any other means, affords a confirmation of these statements, as may be seen more at large in the work above mentioned; nor do I know of a single method of communicating, destroying, increasing, diminishing, or in any way altering magnetism, but what is in perfect accordance with the doctrine here advanced; so are also all kinds of magnetic and electro-magnetic attractions, repulsions, and motions; and the explanations of all these are contained in those of phenomena 2nd and 4th, in the 10th section on electro-magnetism, of the New Theory; the following are explanations of these two phenomena improved in consequence of considering electric atoms as a distinct and separate class.

Let two wires be suspended near each other, parallel, and so that they may easily move towards or from each other, and let an electric current flow along both, as from the positive to the negative side of a voltaic apparatus; then,

1. When the current flows the same way in both; the wires attract each other and adhere, acting as one wire.

2. When the current flows in one direction, along one of the wires, and in the opposite direction along the other; the wires repel each other, and recede to a distance depending on the energy of the current, and their weight.

1. The first of these phenomena is thus explained: The manner in which an electric current flows along a metallic wire was shewn above, and from this it follows, that the electric atoms which pass from the superficial atoms of the wires, and re-enter the same, forming their undulatory course, will pass on their exterior sides, since the coincidence of the two currents between the wires, as to direction, causes them to flow more freely, and renders them more dense on the interior sides, and therefore the one tends to prevent the escape of electric atoms from the other on these, and to promote the same on the exterior sides; but every atom which escapes or returns, produces a repulsion of the wire, as shewn on electrical attraction, towards the opposite parts, which operates through the whole length of the wires, and this not being counteracted by like forces on the opposite interior sides, the wires approach, and adhere, and become as a single conductor; that is they attract each other. This effect is promoted also by the electric atoms, which have left the wire and return towards the denser part of the current.

2. The second phenomenon is thus explained: Since the currents meet each other between the wires, they check each others progress, and the current will flow most freely, and consequently will be most dense on the exterior sides; hence the electric atoms pass off from the wires and return on the interior sides, from which also the extricated atoms, which do not return to the wire, flow towards the denser parts of the current; hence a multitude of forces are continually acting through the whole length of the wires to separate them, which produces the repulsion observed. These two exhibit the type, and contain the principles, and cause of all magnetic, and electro-magnetic attractions, repulsions, and motions, which should thus be, since truth is always consistent with itself: and these explanations shew the correspondence between the flowing of the electric current, and the formation of magnets, as above stated in detail. If a wire be formed into a helix as above represented on the finger of the left hand, and an electric current be made to pass along the same, a needle or piece of hardened steel, placed in the helix, will speedily become a north magnet; but if the helix be such as was formed on the fore finger of the right hand, a south magnet is formed with the same facility.

In confirmation of these statements, the following explanations are given of the usual magnetic attractions and repulsions. First take two north magnets; the fore finger of the left hand may represent one, and that of the right hand, by supposing the course of the spirals to rise between the thumb and finger, and to go off at the tip, or north pole, may represent the other. Laying the tip of the right hand finger on the lower joint of the other, that is a north in contact with a south pole, it will be seen that the course of the spirals, and consequently of the current is the same way in both, and coinciding at the place of contact, the electric atoms, which escape, and those which re-enter the magnets, will do so on that side of the ridges of the spiral channels, which are most remote from the point of contact; hence there are innumerable forces acting, and all of them acting so as to press the two magnets together, which is magnetic attraction.

If the fingers be placed in a line with the tips in contact, that is two

north poles together, it will be seen that the courses of the currents are in opposite directions on the two, where the current leaving one, meets that leaving the other; hence the pressures are thrown on the sides of the channelled spirals, which face the point of contact, and the magnets recede, which is magnetic repulsion: if the two south poles had been in contact, the same would have been evident, since the fluid is entering the magnets in opposite directions.

Again, suppose the left hand finger a north magnet as before, and the right hand finger a south magnet, the spirals in their desending between the thumb and finger, and going off at the tip as a south pole. The tips of the two fingers being now in contact as before, it will be seen, that the fluid is leaving both in the same direction, hence in this case also a north and south pole attract each other: but when the tip of the right hand finger is placed at the lower joint of the left, in a line with it, it will appear that the current proceeds in opposite directions meeting each other, and repulsion occurs.

The amazing force of a piece of soft iron in the shape of a horseshoe magnet, with copper wire wrapped around it, and an electric current passing through the wire, is thus also fully accounted for; as is indeed every instance of such attractions and repulsions.

We cannot enter into the subject of physical optics, but I wish to observe, that the assertions of eminent men ought to be well examined; they ought not to be hastily rejected; nor should they be received without due proof: for since such men are generally followed by the whole train of philosophers, any mistake of theirs carries with it a dead weight with a living force; such I take to be the incautious expression of Professor Airy, who stands as a philosopher, perhaps, second to none in our day; he says, "The undulatory Theory of Optics is presented to the reader as having the same claims to his attention as the Theory of Gravitation: namely, that it is certainly true." Now nothing in philosophy is more certain than the truth of Gravitation, but it is far from being certain that the undulatory theory as generally received is true. Gravitation is a primordial law, the same always and at every place where it exists; no secondary cause is at all indicated; it has, as far as now appears, no cause but the Almighty word of God. It is not so with the undulations; we are not certain, for instance, that they exist in the spaces between us and the sun; it is not only possible, but exceedingly probable, that the undulations, whose existence is inferred from facts, are produced by the actions of luminous atoms emitted from radiant bodies.

Also undulations are not fixed things, they commence, increase, diminish, and terminate; they appear as the effects of a natural cause.

We cannot conceive how gravitation can act, but by means of its innate agency; but all such undulations, as are inferred from phenomena, may be, and doubtless are produced, by atoms of light moving through an ethereal medium, pervading our atmosphere, and all terrestrial bodies; and the chemical processes, which, in nature, are perpetually in operation, are sufficient to account for the motions of these luminous atoms; hence there is no need of the enormous stretch of imagination, which fills the immense spaces of the universe with subtile vibratory ethers; this is a redundancy in the theory, uncalled for: while the same theory labours under a deficiency, in not accounting for the commencements and terminations of the vibratory motions, each of which appears as much an effect of some natural cause, as any phenomena presented to our notice. On the other hand, the theory here proposed, exhibits the causes of the emanations of the luminous atoms; and in their motions, the cause of the vibrations themselves are shewn, such as we observe, although the intermediate spaces of the heavens, which are unoccupied by suns, planets, and comets, and their atmospheres, should be quite void of matter. (See my treatise on Physical Optics, and more especially a paper published in 1835, at Bristol, in the West of England Journal of Science and Literature.) Hence the New Theory embraces all the advantages, both of the theory of emission, and that of undulation, with others not derivable from either of these.

In the preface to the original work will be found an argument to shew the possibility of creation being effected from nothing external, by the energies of an infinite self-existent Being. This argument says the late Dr. Adam Clarke, in one of his letters, " is to me new and sound"; and so it is also in my opinion: hence there is no obstruction to the revealed truth, that In the beginning God created the heavens and the earth;—all beings of every grade; whether all sorts of matter had a beginning at the same instant, or at successive periods, we know not; but we are distinctly informed, that our earth, after its creation, was reduced from a chaotic state by degrees, into its proper form, beauty, and order, according to the power of God working in wisdom and goodness.

At first all was darkness, then the spirit of Elohim, which probably means the electric fluid, moved on the surfaces of the tenacious atoms, that is on the faces of the waters; then light emanated from the dark masses in consequence of the energetic chemical actions just put into active operation: whether the light was then created, or then first made to emanate, and act as light: and thus the light was separated from the darkness: and such separation of light from darkness, we still see in the burning of bodies: and all this is effected by the Word of God; by this every thing has its laws, its operations, its effects; and by this Word every thing is upheld; God said let it be so, and it was so; God regarded the work of his hands, and saw that it was good.

The encomiums which the original paper obtained when first read, have induced me to add some observations on Comets, in order that the merits of the theory may be farther tried in another and distinct field of inquiry.

OBSERVATIONS ON COMETS.

COMETS in all ages have justly excited the notice and admiration, not only of the unlettered, but even of the astronomer himself: multitudes of conjectures and theories concerning them have been framed and published, but nothing satisfactory has appeared, except some little, which relates to their motions, densities, distances, and magnitudes: the larger comets displaying their luminous trains, or tails, present a spectacle at once majestic, and awfully grand.

Six or seven hundred comets have been observed, but this must be a very small number of those which have traversed the solar system.

Many thousand comets are silently and steadily pursuing their courses in the regions of space around us; the small ones, visible only by means of the telescope, or telescopic comets, are by far the most numerous, besides multitudes, as we may justly allow, which are not to be seen by the best instruments; as far as observations go, they appear to move in the curves of conic sections, confirming the law of gravitation; but admitting that law, which has been otherwise incontestibly established, it follows that they must move in such curves, excepting the disturbances occasioned in their motions by other bodies: they move in various directions, at different inclinations to the ecliptic, which the planes of their orbits cut in every variety of position. It was formerly thought that the comets have a firm solid nucleus, but modern and more accurate observations set aside this opinion, except in a few rare cases, which exhibit some indications of a small solid central body: but in general it seems evident, that the solar rays readily pass through the central parts of the comet, and render it luminons. A good telescope shews that there is in most comets a round central part thus equally luminous, and which may be called the nucleus, and that this is enclosed in a sort of envelope, called the head, and seems to be of the nature of a thin atmosphere, and that this is again generally enclosed in a sort of nebulous haziness, called the coma, from which frequently issue two or more streams of light, spreading into each other, and forming the tail, and sometimes several tails: the tails of comets are sometimes very long, in other cases short, and some even bright comets, have no tails: but these appendages, when they exist, always extend in the regions opposite to the sun. The figures and sizes even of the same comet, are sometimes altered in a few days: they seem to consist of nothing but a collection of thin vapours, vastly thinner than our most attenuated fogs; some of them have no nucleus, and some throw out beams like hair on every side. The smallest stars may be seen through the tails, coma, and heads, with a small diminution of brightness, although the thickness of vapour through which they are viewed is often many million miles; the stars are seldom seen through the nucleus, perhaps because of its brightness: the smallness of the quantity of matter in comets is also fully proved from this, that they do not disturb sensibly the planets, or satellites to which they make a near approach, while their own motions are greatly disturbed: it is probable that some comets are almost or entirely dissipated in the solar regions. The atmospheres of the comets, which include the heads and coma are often extensive, and the exterior visible parts or coma especially exhibit the appearance of great perturbation and agitation of their parts; the atmospheres evidently will extend much farther than the visible parts of them which comprehend the head and coma. By far the greater number of comets have their perihelia nearer the sun than the earth is, and their aphelia at a very great distance.

Since comets are seen only in the lower parts of their orbits, the periods of very few are known; that of Dr. Halley is very remarkable, its periodical revolution is performed in about $75\frac{1}{2}$ years: in some of its late returns its splendour has diminished. Professor Encke of Berlin determined the period of a comet, called Encke's comet; its orbit is very eccentric, inclined to the ecliptic 3° 22′, its period about $3\frac{1}{3}$ years, and it is found that its mean distance from the sun undergoes some diminution. The comet of Biela, performs its period of revolution in about $6\frac{3}{4}$ years, in an orbit moderately elliptical. For further illustration we may mention two or three instances; the comet seen January 1793, was remarkable for its haziness, of an oval form, having a faint tail, but no nucleus: that seen November 7th. 1795, had no nucleus, but consisted of an ill defined haziness, somewhat strongest in the middle: that observed by M. Pons, November 11th. 1806, was small, shapeless, and without nucleus: that carefully observed by Sir W. Herschel, in 1807, had a small round nucleus, equally luminous, and very bright, this was surrounded by the luminous head, which itself was involved in the nebulous like coma, the nucleus subtended an angle of about 1″, that of the coma 4″, the tail sometimes extended $3\frac{1}{2}°$, the two streams forming the tail were of different lengths, sometimes one, sometimes the other, being the longer. The comet of 1811, was also with very great attention observed by Sir W. Herschel: the diameter of the lucid nucleus was about 428 miles, and not quit in the centre of the head, which had the appearance of a fine nebula about 300 times greater in diameter than the nucleus: the head, which observation shewed to be an elastic atmosphere, was in diameter about 1200 times greater, and had a luminous envelope or coma 1500 times greater than that of the nucleus: the length of the tail was sometimes 100 millions of miles, and its breadth 15 millions of miles; two streams of light flowing from the sides of the coma, or envelope, extended to the regions opposite the sun, and enclosed the tail, scattering their light into it as they proceeded, sometimes the one and sometimes the other being the longer: it was established by the observations, that the bright envelope was an hemispherical shell with its vertex towards the sun, sending out a hollow cone of light produced by the action of the sun, involving within it the comet's tail: also that as the comet receded from the sun it began to acquire a globular form, as was evident from actual physical changes observed in its construction. It was concluded from the phenomena that the comet revolves on an axis. The tails of comets always increase as they approach the perihelion, and are greatest of all soon after they return from that point.

In order to give an idea of these, and other peculiarities of comets, we now proceed to consider the particulars concerning which no satisfactory explanation has been given, notwithstanding the inundation of conjecture poured forth on every side. The sun is continually emitting a vast body of light in all directions, with a velocity of about 200000 miles per second, also calorific rays are emitted, probaby with much less velocity. The planets reflect light, and emit abundance of it from the burning of bodies, and other chemical processes; and emanations of caloric must also be produced, often with velocities so small that they return to the planet. But not only does ethereal matter thus proceed from the sun and planets, but also abundance of electric and tenacious atoms are projected, especially the former.

Now setting aside the resistance of the atmosphere, if a body be projected with a velocity of seven miles per second, which is but about 12 or 14 times greater than that which can be given to a cannon ball, it would leave the earth, and never return, but would move very slowly after reaching the confines of the solar system; and a much greater velocity is probably given, not only to electric atoms, but even to those of the tenacious class in some cases of chemical actions, and concussions of nature; and the motion of such atoms will not be any thing like so much impeded as that of extensive bodies: Dr. Keill states, that, "a great quantity of fine lucid vapour was lately thrown out from the *earth* to an immense height above the air, so that it was visible through the greatest part of *Europe*." Similarly each of the innumerable systems of suns and planets will be pouring forth atoms from all quarters of the heavens, and multitudes of these will be found moving very slowly in the neighbourhood of our system.

There is besides, another source of motion in the several classes of atoms. And that is the solar rays, which are continually falling on the atoms of air. These will produce, it is true, but little, indeed an imperceptible, motion in the atoms of the denser parts of the atmosphere; because the atoms in these places are supported by pressure on all sides; but it is different in respect to the upper and thin parts of the air; the rays falling on these will propel them in the direction of the light, while they reflect the same light; and although the action of one atom of light may be small, that of many thousands of such atoms produce a great effect in these circumstances, making even tenacious atoms to vibrate probably through spaces very considerable; this applies more especially to the extremes of the solar atmosphere, because the light is much more dense; much light will emanate from these vibrating atoms, and this is probably the chief cause of the zodiacal lights; but these motions will be comparatively small on account of the strong attractions of the planets. Leaving for the present these, and all such atoms as return to their respective planets, let us fix our attention on those which are slowly moving in space, and which being projected with all sorts of directions and velocities, will move in all the kinds of conic sections, but especially in ellipses and hyperbolas; now when two, three, or any number of the tenacious atoms, moving with great slowness in these distant regions, come near together, they will be there the principal attracting bodies, and will not only attach, each to itself a very large atmospherule of electric and tenacious atoms, but will also on account of their various motions, revolve about each other, or rather about their common centre of gravity, as a minute system, and this centre will itself be carried in a cônic section about the centre of gravity of the solar system. In the process of ages, if not by some means prevented, an immense number of such systems would be formed, so that they would accumulate in time to an injurious degree, by retarding the motions of the planets. We may therefore conclude that comets were prepared through the goodness and wisdom of the Creator, and placed in suitable regions of space, at proper distances from our system; and that they were impressed with suitable motions in the best directions, to answer the purpose of collecting these dispersed atoms of the several classes, and bringing them again to the planetary regions, not universally diffused, but collected; their several tenacious atoms will become loaded with abundance of electric and ethereal atoms, sweeping and clearing the spaces through which they pass, to a very great distance on every side, and will also cause a multitude of the other little systems to revolve about them as so many secondary comets. But from the occurrence of others of these minute systems, frequently many of them will be absorbed in the body of the primary comet.

This account, which is a necessary deduction from the theory before us, shews at once the origin, formation, nature and use of comets; and every thing observed respecting them, will perfectly agree with this account, and from it the phenomena are easily explicable. Thus their formation, or perhaps rather completion, from their continual accessions of matter, moving in different directions, will often produce a rotation more or less rapid; much tenacious matter, with a redundancy of electric and ethereal atoms, will accumulate at the centre forming the nucleus; which on these grounds will evidently be surrounded by a very extensive elastic atmosphere, also loaded with electric and ethereal matter, and held down with an exceedingly minute force, but yet the greatest which is acting in these regions, and this will form the head; now the solar rays, falling on the atoms of this head, will, especially at its exterior parts, produce a motion in them, in a direction *from* the sun, especially when they are at or near the perihelion; for although, on account of the exceedingly minute quantity of matter in an atom of light, its momentum, notwithstanding its great velocity, is very small; yet when we consider that innumerable atoms of light fall at once on each atom of the comet's head, and on its external atmospherule of electric and ethereal matter, and that they fall in rapid succession, much motion will be produced; and more especially because of the exceedingly minute force by which the tenacious atom and its atmospherule is held down to the centre of the comet, it will be propelled with great velocity; the atoms of light falling on it will of course be reflected back, and the tenacious atom, and its atmospherule, driven forward, and by these actions abundance of light will be discharged from the atmospherule of the atom, as well as the reflected solar beams, and this will form the hemispherical cup, envelope or coma, on the side facing the sun; but the atoms of the head near the base of the hemispherical cup will have liberty of motion, and many of them will be propelled millions of miles, more or less according to circumstances, and will scatter the abundance of ethereal

matter, which they had collected, in the form of light and heat; while the electric atoms will also be extricated in abundance, increasing the general effect, and producing all the phenomena of the tail. There will be great differences in the atmospheres of comets, arising from their quantity of matter, the regions through which they have passed, and other circumstances, and many, especially of the smaller comets, will have no tails as we find in fact. The planets have no tails; first, because the atoms on their atmospheres are held to the planets by their powerful attractions; and second, being at an uniform moderate distance from the sun, their atmospherules are not so abundantly charged with electric and ethereal atoms. Again, from the whole of this account, it is manifest that the tails ought to be greatest when nearest the sun, and the more so just after they begin to return; and that in the more distant parts of their regression, they will again accumulate their matter into a globular form.

Thus then we see that the comets hold an important office, and that they are instituted for the beneficent purpose of preserving the general order, arrangement and harmony of the several grand parts of the material world; and for preventing the dispersion of matter, and the obstructions which that dissipated matter would produce.

Thus comets conspire with the other parts of the creation to celebrate the praises of Him from whom they receive all their majesty and beauty. The more we examine the constituent parts of the universe, either in its very extensive collections of matter, or in the minutest forms of the smallest bodies, the more we must admire; till our minds are fixed with speechless awe in the grandeur of the subject; while, melted down under the impression, they are carried forward in solemn reverence, and delightful adoration, to worship Him who created the heavens and the earth.

In submitting this paper to public notice, allow me to add, that, in my opinion, it is a strong confirmation of the " New Theory of Physics," published in 1829, which is already held in high estimation by competent judges. Nothing has been advanced from any quarter, which can at all invalidate its principles, or the results of its legitimate applications. Its reception by chemists of the greatest eminence, at the British Association, was to me highly gratifying. The reviews which have appeared speak much in its favour. Professor Airy, in reference to my Treatise on " Physical Optics," justly observes, that " the real foundation for successful theories in every case has been calculation." This is true; but what successful theories have been framed, except the theory of gravitation? He adds, it would be well to apply it in calculating the complicated cases of diffraction, and depolarization, " the whole of which are given most correctly by calculation on the undulatory theory." I have thought it more advisable, and more in the order of the synthetical procedure, to shew the bearing of my principles on the last results of experiment, and thus shew the importance of the principles, by establishing from them the only real foundations of Natural Philosophy. While I freely admit that calculation is necessary for successful theory, I cannot allow that it is an indubitable proof of its truth;

thus calculation will give correct results in relation to electrical phenomena, on the theory of Franklyn, or that of Du Fay; but certainly both are not true, I am persuaded both are false: similar observations apply in optics to the undulatory theory and that of emission, and yet probably neither of them is true. Professor Whewell, in some remarks which he did me the favour to make on this paper, before it was publicly read, observed that, " from the number of facts which this theory includes, and the laws which it undertakes to explain, I think it very possible that some generalization of real value may be contained it it." He added some excellent criticisms, by which I was enabled greatly to improve the paper. Allow me therefore earnestly to recommend philosophers to make trial of these principles: if possible shew that they are incorrect or insufficient; but if this cannot be done, let their validity be candidly acknowledged.

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