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CHEMICAL CONCEPTION OF THE ETHER

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A CHEMICAL CONCEPTION OF THE ETHER

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BY THE SAME AUTHOR

THE PRINCIPLES OF CHEMISTRY

Translated from the Russian (Sixth Edition)

By GEORGE KAMENSKY, A.R.S.M.

of the Imperial Mint, St. Petersburg

AND

Edited by T. A. LAWSON, B.Sc., Ph.D.

With 96 Illustrations. 2 vols. 8vo. 36*s*.

LONGMANS, GREEN, & CO. 39 Paternoster Row, London
New York and Bombay.

AN ATTEMPT TOWARDS A CHEMICAL CONCEPTION OF THE ETHER

BY

PROFESSOR D. MENDELÉEFF

TRANSLATED FROM THE RUSSIAN

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LONGMANS, GREEN, AND CO.

39 PATERNOSTER ROW, LONDON

NEW YORK AND BOMBAY

1904

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A
CHEMICAL CONCEPTION OF THE ETHER

In his 'Dictionnaire Complet,' P. Larousse defines the ether as 'an imponderable elastic fluid, filling space and forming the source of light, heat, electricity, etc.' This is laconic, but sufficient to raise some misgivings in the mind of a thoughtful man of science. He is obliged to admit, in the ether, the properties of a substance (fluid), while at the same time, in order to explain in some way the transmission of energy through space by its motion, the ether is assumed to be an all-pervading 'medium.' Moreover, in order to explain the phenomena of light, electricity, and even gravity, this medium is supposed to undergo various disturbances (perturbations) and changes in its structure (deformation), like those observed in solids, liquids, and gases. If the fluid medium permeates everything and everywhere, it cannot be said to have weight,

just as the ponderability of air could not be recognised before the invention of the air-pump. Yet the ether must have weight, because, since the days of Galileo and Newton, the quality of gravitation or of weight forms a primary property of substances. From various considerations Lord Kelvin came to the conclusion that a cubic metre of ether should weigh about and not less than 0·000,000,000,000,000,1 grm., while a cubic metre of the lightest gas, hydrogen, weighs 90 grams under the atmospheric pressure. The above-mentioned misgivings of the thoughtful scientist begin in his most plausible endeavours to ascribe a certain weight or mass to the ether, for the question naturally arises: At what pressure and temperature will this weight be proper to ether? For at infinitely small pressures or exceedingly high temperatures steam or hydrogen would have as small a density as that given by Lord Kelvin for the ether. And as regards the density of the ether in interplanetary space, neither steam nor hydrogen would have a measurable density in these regions, notwithstanding the extreme cold, for the pressure would be infinitely small. Theoretically, space may be supposed to be filled with such rarefied residues of vapours and gases. And this view even

corresponds with Kant's and Laplace's and other theories, which strive to explain the unity of plan in the creation of the heavenly bodies. It also accounts for the uniformity of the chemical composition of the entire universe, demonstrated by the spectroscope, as it gives a means, through the agency of such ether, of interchange between the heavenly bodies. One of the objects of an investigation into the elasticity or compressibility of gases under low pressure, undertaken by me in the seventies, was to trace, as far as the then existing methods of measuring low pressures permitted, the changes proceeding in gases under low pressures. The discrepancies from Boyle's law observed (by me and M. Kirpitchnikoff, 1874) for all gases, and subsequently confirmed by Ramsay and others (although still denied by some investigators), indicate a certain uniformity in the behaviour of all gases and a tendency in them towards a certain limiting expansion at low pressures, just as there is a limit to compression (liquefaction and the critical state). But determinations of very low pressures are accompanied by insurmountable difficulties. It proved practically impossible to measure, with any degree of accuracy, pressures under tenths of a millimetre of mercury, and this is far

too large a figure for such rarefied media as are supposed to exist at an elevation of even 50 kilometres above the sea level. Hence the conception of the ether as a highly rarefied atmospheric gas cannot so far be subjected to experimental investigation and measurement, which alone can direct the mind in the right direction and lead to reliable results.

But, beyond this, the conception of the ether as a limiting state of expansion of vapours and gases cannot sustain even the most elementary analysis, for ether cannot be understood otherwise than as an all-pervading ubiquitous substance, and this is not the property of either gases or vapours. Both the latter are liquefiable under pressure, and cannot be said to permeate all substances, although they are widely distributed in nature, even in meteorites. Moreover—and this is the most important—they vary infinitely in their chemical nature and in their relations to other substances, while the ether, as far as is known, is invariable. Owing to the variety of their chemical properties, all vapours and gases should react differently on the bodies which they permeate if they were components of the ether.

Before proceeding further, I think it necessary to justify the chemical views here and

elsewhere brought into play. In the days of Galileo and Newton it was possible, although difficult, to conceive ether apart from them. But now it would be contrary to the most fundamental principles of natural science, for chemistry, since Lavoisier, Dalton, and Avogadro Gerhardt, has acquired the most sacred rights of citizenship in the great company of the natural sciences, and by placing the mass (weight) of a substance among its paramount conceptions it has followed the path indicated by Galileo and Newton. Moreover, chemistry and its methods alone have promoted in science a desire to apprehend bodies and their phenomena in their ultimate relations, through a conception of the reaction of their infinitely small parts or atoms which may in fact be regarded as indivisible individuals, having nothing in common with the mechanically indivisible atoms of the ancient metaphysicians. There are many proofs of this; it will suffice to mention the fact that the atoms of modern science have often been explained by vortex rings, that there was formerly a strong inclination to conceive the chemical atoms as built up of themselves, or of a 'primary matter,' and that recently, especially in speaking of the radio-active substances, a division of chemical

atoms into yet smaller 'electrons' begins to be recognised; all of which would be logically impossible were the atom regarded as mechanically indivisible. Chemically the atoms may be likened to the heavenly bodies, the stars, sun, planets, satellites, comets, &c. The building up of molecules from atoms, and of substances from molecules, is then conceived to resemble the building up of systems, such as the solar system, or that of twin stars or constellations, from these individual bodies. This is not a simple play of words in modern chemistry, nor a mere analogy, but a reality which directs the course of all chemical research, analysis, and synthesis. Chemistry has its own microscope for investigating invisible regions, and being an archi-real science it deals all the time with its invisible individualities without considering them mechanically indivisible. The atoms and molecules which are dealt with in all provinces of modern mechanics and physics cannot be other than the atoms and molecules defined by chemistry, for this is required by the unity of science. And therefore the metaphysicians of the present day should, for the advancement of knowledge, regard atoms in the same sense as that in which they are understood by natural science and not after the manner of the

ancient metaphysicians of the Chinese or Greek schools. If the Newtonian theory of gravity revealed the existence of forces acting at infinitely great distances, the chemistry of Lavoisier, Dalton, and Avogadro Gerhardt, on the other hand, disclosed the existence of forces of immense power acting at infinitely small distances, and transmutable into all other forms of energy, mechanical and physical. Thus all the present-day fundamental conceptions of natural science—and consequently the conception of the ether—must necessarily be considered under the combined influence of chemical, physical, and mechanical teachings. Although sceptical indifference is prone to discern only a 'working hypothesis' in the conception of the ether, yet the earnest investigator, seeking the reality of truth, and not the image of fantasy, is forced to ask himself what is the chemical nature of the ether.

Before endeavouring to give an answer respecting the chemical nature of ether, I think it necessary to state my opinion regarding the belief held by some in the unity of the substance of the chemical elements and their origin from one primary form of matter. According to this view, ether consists of this primary matter in an unassociated form, that is, not in the form of the

elementary atoms or molecules of substances, but as the constituent principle out of which the chemical atoms are formed. This view has much that is attractive. The atoms are regarded as proceeding from primary matter in the same way as celestial bodies are sometimes represented as being formed from disunited bodies, such as cosmic dust, etc. The celestial bodies so formed remain surrounded by the cosmic dust, etc., from which they took their origin. So also the atoms remain in the midst of the all-pervading and primary ether from which they took their origin. Some persons assume also that atoms can be split up into their dust or primary matter, just as comets break up into falling stars; and that, as the geological changes of the earth or the building up and dissociation of heavenly bodies proceed before our eyes, so also do the atoms break up and form again in the silence of their eternal evolution. Others, without denying the possibility of such a process in exceptional rare cases, consider the world of atoms to have been established once for all, and do not admit the possibility of decomposing the atom into its primary matter, or of forming new atoms of any chemical element from this primary matter by experimental means. In a word, they regard

the process of the creation of atoms as finite and not subject to repetition, while they consider the ether as the residue remaining after the formation of atoms. This view need not be considered here, it being solely the fruit of imagination and unproved by any experimental investigation. But the former theory of a progressive evolution of the substance of atoms cannot be passed unnoticed by chemistry, for fundamental principles of this science are the indestructibility of matter and the immutability of the atoms forming the elements. If ether were producible from atoms and atoms could be built up from ether, the formation of new unlooked-for atoms and the disappearance of portions of the elements during experiment would be possible. A belief in such a possibility has long been held in the minds of many by force of superstition; and the more recent researches of Emmens to convert silver into gold, and those of Fittica (1900) to prove that phosphorus can be transformed into arsenic, show that it yet exists. In the fifty years during which I have carefully followed the records of chemistry, I have met with many such instances, but they have always proved unfounded. It is not my purpose here to defend the independent individuality of the chemical elements, but I

am forced to refer to it in speaking of the ether, for it seems to me that, besides being chemically invalid, it is impossible to conceive of ether as a primary substance, because such a substance should have some mass or weight and also chemical relations—mass in order to explain the majority of phenomena proceeding at all distances up to the infinitely great, and chemical relations in order to explain those proceeding at distances infinitely small or commensurable with the atoms. If the question were restricted to the ether which fills space and serves as a medium for the transmission of energy, it would in a way be possible to limit oneself to the supposition of mass without reference to its chemical relations and even to consider the ether as a primary matter, just as the mass of a planet may be conceived without regarding its chemical composition. But such an indifferent, indefinite ether loses all sense of reality and awakens the misgivings of the earnest investigator, directly he realises that it must permeate all substances. The necessity of an easy and perfect permeation of all bodies by the ether has to be admitted, not only for the comprehension of many physical phenomena (such as those of optics), but also owing to the great elasticity and rarity of the ethereal substance,

the atoms of which are always conceived as being far more minute than the atoms and molecules of the known chemical substances. Moreover, this permeability of ether in all bodies explains why it cannot be isolated from substances, which indeed behave in respect to ether like a sieve to water or air. The capacity of the ether to penetrate all substances may, however, be regarded as the ideal of the diffusion of gases through metals and other diaphragms. Hydrogen, which has a small atomic weight and is the lightest of all known gases, not only diffuses more rapidly than any other gas, but also has the faculty of penetrating through walls of such metals as platinum and palladium, which are impervious to other gases. This property is certainly due, not only to the rapidity of the motion of the molecules of hydrogen, closely connected with its small density, but also to a chemical faculty of the same kind as is exhibited in the formation of metallic hydrides, of solutions, alloys, and other indefinite compounds. The mechanism of this penetration may be likened (at the surface of the body penetrated) to the solution of a gas in a liquid, that is, to the gaseous particles leaping into the interstices between the particles of the liquid with a retardation of their motion (a partial liquefaction

of the gas), and a bringing into harmony of the motion of both kinds of particles. The condensed gas absorbed at the surface of contact travels in all directions through the body, and diffuses from one layer to another until it entirely permeates it. The possibility of gaseous hydrogen acting thus is evident from the fact that even gold diffuses through solid lead under the same force. At length, at the opposite surface of the body penetrated, the condensed gas will find it possible to escape into greater freedom, and will continue to pass in this direction until its degree of concentration becomes the same on both sides. When this takes place it does not set up a state of rest, but one of mobile equilibrium, that is, equal numbers of molecules or atoms will escape and leap in on the two sides. If, as it must, ether have the faculty of permeating all substances, it must be even lighter and more elastic (greater *vis viva*) than hydrogen, and, what is most important, must have a less capacity than hydrogen to form chemical compounds with the bodies it permeates. Compounds are characterised by the fact that the diverse atoms in them form systems or molecules, in which the different elements are in compatible, harmonious motion. We must therefore suppose that such

a state of harmonious motion, of, for instance, hydrogen and palladium, is actually set up in those atoms of hydrogen which permeate the palladium, and that in so doing it forms with the palladium some compound (either Pd_2H or another) which easily dissociates when heated. Hence it seems to me that the atoms of ether are so void of this faculty of forming compounds (which is already weak in hydrogen) that such compounds dissociate at all temperatures, and that therefore nothing beyond a certain condensation among the atoms of substances can be looked for in the ether.

Eight years ago, it would have been most arbitrary to deny the existence, in the substance or atoms of ether, of the faculty of forming any compounds with other chemical elements, for in those days all the known elements were, directly or indirectly, capable of entering into mutual combination. But in 1894 Lord Rayleigh and Professor Ramsay discovered argon, and defined it as the most inactive element; this was followed by the discovery of helium, the existence of which Lockyer had predicted by its spectrum as a solar element, and subsequently by the separation of neon, krypton, and xenon from air. None of these five new gases have yet given any definite

compounds, although they clearly evince the faculty of solution, *i.e.* of forming indefinite, easily dissociated compounds. Thus we have now every right to say that the ether is unable to form any stable compounds with other chemical atoms, although it permeates all substances.

Hence *the ether may be said to be a gas, like helium or argon, incapable of chemical combination.* This definition of ether requires further consideration. The recognition of the ether as a gas, signifies that it belongs to the category of the ordinary physical states of matter, gaseous, liquid, and solid. It does not require the recognition of a peculiar fourth state beyond the human understanding (Crookes). All mystical, spiritual ideas about ether disappear. In calling ether a gas, we understand a 'fluid' in the widest sense; an elastic fluid having no cohesion between its parts. Furthermore, if ether be a gas, it has weight; this is indisputable, unless the whole essence of natural science, from the days of Galileo, Newton, and Lavoisier, be discarded for its sake. But since ether possesses so great a penetrative power that it passes through every envelope, it is, of course, impossible to experimentally determine its mass in a given amount of other substances, or the

weight of a given volume of ether. We ought, therefore, not to speak of the imponderability of ether, but only of the impossibility of weighing it.

The preceding remarks are in exact accordance with the generally accepted conception of ether. The only addition made is to ascribe to ether the properties of a gas, like argon and helium, utterly incapable of entering into true chemical combination. This point lies at the basis of our investigation into the chemical nature of ether, and includes the following two fundamental propositions: (1) that the ether is the lightest (in this respect ultimate) gas, and is endowed with a high penetrating power, which signifies that its particles have, relatively to other gases, small weight and extremely high velocity, and (2) that ether is a simple body (element) incapable of entering into combination or reaction with other elements or compounds, although capable of penetrating their substance, just as helium, argon, and their analogues are soluble in water and other liquids.

The argon group of gases and the periodic system of the elements have such a close bearing upon our further consideration of the chemical nature of ether that it behoves us to look at them more closely.

When in 1869 I first showed the periodic dependence of the properties of the elements upon their atomic weights, no element incapable of forming definite compounds was known, nor was the existence of such an element even suspected. Therefore the periodic system was arranged by me in groups, series, and periods, starting in group I. and series I., with hydrogen as the lightest and least dense of all the elements. It never occurred to me that hydrogen might be the starting-point of a system of elements. Guided by this system, I was able to predict both the existence of several unknown elements and also their physical and chemical properties in a free and combined state. These elements, gallium, scandium, and germanium, were subsequently discovered by Lecoq de Boisbaudran, Nilson, and Winkler respectively. I made these predictions by following what is known in mathematics as a method of interpolation, that is, by finding intermediate points by means of two extreme points whose relative position is known. The fact of my predictions having proved true confirmed the periodic system of the elements, which may now be considered as an absolute law. So long as the law remained unconfirmed, it was not

possible to extrapolate (*i.e.* to determine points beyond the limits of the known) by its means, but now such a method may be followed, and I have ventured to do so in the following remarks on the ether, as an element lighter than hydrogen. My reason for doing this was determined by two considerations. In the first place, I think I have not many years for delay; and, in the second place, in recent years there has been much talk about the division of atoms into more minute electrons, and it seems to me that such ideas are not so much metaphysical as metachemical, proceeding from the absence of any definite notions upon the chemism of ether, and it is my desire to replace such vague ideas by a more real notion of the chemical nature of the ether. For until some one demonstrates either the actual transformation of ordinary matter into ether, or the reverse, or else the transformation of one element into another, I consider that any conception of the division of atoms is contrary to the scientific teaching of the present day; and that those phenomena in which a division of atoms is recognised would be better understood as a separation or emission of the generally recognised and all-permeating ether. In a word, it seems

to me that the time has arrived to speak of the chemical nature of ether, all the more so since, so far as I know, no one has spoken at all definitely on this subject. When I applied the periodic law to the analogues of boron, aluminium, and silicon, I was thirty-three years younger than now, and I was perfectly confident that sooner or later my prediction would be fulfilled. Now I see less clearly and my confidence is not so great. Then I risked nothing, now I do. This required some courage, which I acquired when I saw the phenomena of radio-activity. I then saw that I must not delay, that perhaps my imperfect thoughts might lead some one to a surer path than that which was opened to my enfeebled vision.

First, I will treat of the position of helium, argon, and their analogues in the periodic system; then of the position of ether in this system; and conclude with some remarks on the probable properties of ether according to the position it occupies in the periodic system.

When, in 1895, I first heard of argon and its great chemical inertness, I doubted the elementary nature of the gas, and thought it might be a polymeride of nitrogen N_3, just as ozone, O_3, is a polymeride of oxygen, with the difference

that, while ozone is formed from oxygen with the absorption of heat, argon might be regarded as nitrogen deprived of heat. In chemistry nitrogen was always regarded as the type of chemical inertness, *i.e.* of an element which enters into reaction with great difficulty, and if its atoms lost heat in becoming condensed by polymerisation from N_2 to N_3, it would form a still less active body; just as silica, which is formed from silicon and oxygen with the evolution of heat, is more inert than either of them separately. Berthelot subsequently published a similar view on the nature of argon, but I have now long discarded this and consider argon to be an independent element, as Ramsay held it to be from the very beginning. Many reasons induced me to adopt this view, and chiefly the facts that (1) the density of argon is certainly much below 21, namely about 19, that of H being 1, while the density of N_3 would be about 21, for the molecular weight of $N_3 = 14 \times 3 = 42$ and the density should be half this; (2) helium, discovered by Ramsay in 1895, has a density of about 2 referred to hydrogen, and exhibits the same chemical inactivity as argon, and in its case this inactivity can certainly not be due to a complexity of its molecule; (3) in their newly discovered neon, krypton, and xenon, Ramsay and

Travers found a similar inactivity which, in these cases also, could not be explained by polymerisation ; (4) the independent nature of the separate spectra of these gases, and the invariability of these spectra under the influence of electric sparks, proved that they belong to a family of elementary gases different from all other elements, and (5) the graduation and definite character of the physical properties in dependence upon the density and atomic weight further confirm the fact of their being simple bodies, whose individuality, in the absence of chemical reactions, can only be affirmed from the constancy of their physical features. An instance of this is seen in the boiling points (at 760 m.m.) or temperatures at which the vapour pressures equal the atmospheric pressure and at which the liquid and gaseous phases are co-existent :

—	Helium	Neon	Argon	Krypton	Xenon
Atomic weight .	4	19·9	38	81·8	128
Observed density	2	9·95	18·8	40·6	63·5
Observed boiling point . .	−262°	−239°	−187°	−152°	−100°

This recalls the halogen group :

—	Fluorine	Chlorine	Bromine	Iodine
Molecular weight . .	38	79·9	159·9	254
Vapour density . .	19	35·5	80	127
Boiling point . .	−187°	−34°	+57·7°	+183·7°

In both cases the boiling point clearly rises with the atomic or molecular weight. When the elementary nature of the argon analogues and their characteristic chemical inactivity were once proved, it became essential that they should take their place in the periodic system of the elements; not in any of the known groups but in a special one of their own, for they exhibited new, hitherto unknown chemical properties, and the periodic system embraces in different groups those elements which are analogous in their fundamental chemical properties, although not in dependence upon these properties but upon their atomic weight, which apparently —previous to the discovery of the periodic law— stands in no direct relation to these properties. This was a critical test for the periodic law and the analogues of argon, but they both stood the test with perfect success; that is, the atomic weights, calculated from the observed densities, proved to be in perfect accordance with the periodic law.

Although I assume that the reader is acquainted with the periodic law, yet it may be well to mention that if the elements be arranged in the order of their atomic weights it will be found that similar variations in their chemical

properties repeat themselves periodically, and that the order of the faculty of the elements to combine with other elements also corresponds with the order of their atomic weights. This is seen in the following simple example.

All the elements having an atomic weight of not less than 7 and not more than 35·5 fall into two series:

Li = 7·0	Be = 9·1	B = 11·0	C = 12·0	N = 14·0	O = 16	F = 19·0
Lithium	Beryllium	Boron	Carbon	Nitrogen	Oxygen	Fluorine
Na = 23·0	**Mg = 24·3**	**Al = 27·0**	**Si = 28·4**	**P = 31·0**	**S = 32·1**	**Cl = 35·5**
Sodium	Magnesium	Aluminium	Silicon	Phosphorus	Sulphur	Chlorine

Each pair of elements present a great similarity in their chief properties; this is especially marked in the higher saline oxides, which in the lower series are:

$$Na_2O,\ MgO,\ Al_2O_3,\ SiO_2,\ P_2O_5,\ SO_3,\ Cl_2O_7,$$

or

$$Na_2O,\ Mg_2O_2,\ Al_2O_3,\ Si_2O_4,\ P_2O_5,\ S_2O_6,\ Cl_2O_7.$$

Thus the atomic order of the elements exactly corresponds to the arithmetical order from 1 to 7. So that the groups of the analogous elements may be designated by the Roman ciphers I to VII: and when it is said that phosphorus belongs to group V, it signifies that it forms a higher saline oxide P_2O_5. And if the analogues of argon do not form any compounds of any kind, it is evident that they cannot be included

in any of the groups of the previously known elements, but should form a special zero group which at once expresses the fact of their chemical indifference. Moreover, their atomic weight should necessarily be less than those of group I: Li, Na, K, Rd, and Cs, but greater than those of the halogens, F, Cl, Br, and I, and this *a priori* conclusion was subsequently confirmed by fact, thus:

Halogens	Argon analogues	Alkali metals
	He=4·0	Li=7·03
F=19	Ne=19·9	Na=23·05
Cl=35·5	Ar=38	K=39·1
Br=79·95	Kr=81·8	Rh=85·4
I=127	Xe=128	Cs=132·9

The five well-known alkali metals correspond to the newly discovered argon analogues, and the atomic weights of both exhibit the same common law of periodicity. But the halogens and alkali metals are the most chemically active among the elements, and are, moreover, of opposite chemical character, the first being particularly prone to react with metals and the others with metalloids, the former appearing at the anode and the latter at the cathode. They must therefore stand at the two extremes of the periodic system, as in the scheme on page 24.

Although this arrangement best expresses

—					Higher saline oxides	Groups	Large periods. Elements of even series				—
Distribution of the Elements in Periods					R^2O	I	K = 39·1	Rb = 85·4	Cs = 132·9	—	Rd = 224
					RO	II	Ca = 40·1	Sr = 87·6	Ba = 137·4	—	Th = 232
					R^2O^3	III	Sc = 44·1	Y = 89·0	La = 139	Yb = 173	U = 239
					RO^2	IV	Ti = 48·1	Zr = 90·6	Ce = 140	—	—
					R^2O^5	V	V 51 ·4	Nb = 94·0	—	Ta = 183	—
					RO^3	VI	Cr = 52·1	Mo = 96·0	—	W = 184	—
					R^2O^7	VII	Mn = 55·0	? = 99·4	—	—	—
						VIII	Fe = 55·9	Ru = 101·7	—	Os = 191	—
							Co = 59	Rh = 103·0	—	Ir = 193	—
							Ni = 59	Pd = 106·5	—	Pt = 194·9	—
Gaseous hydrides	Higher saline oxides	Groups	Small periods. Typical elements								
	R^2O	I	H = 1·008	Li = 7·03	Na = 23·05		Cu = 63·6	Ag = 107·9	—	Au = 197·2	—
	RO	II		Be = 9·1	Mg = 24·3		Zn = 65·4	Cd = 112·4	—	Hg = 200·0	—
	R^2O^3	III		B = 11·0	Al = 27·0		Ga = 70·0	In = 114·0	—	Tl = 204·1	—
RH^4	RO^2	IV		C = 12·0	Si = 28·4		Ge = 72·3	Sn = 119·0	—	Pb = 206·9	—
RH^3	R^2O^5	V		N = 14·04	P = 31·0		As = 75·0	Sb = 120·0	—	Bi = 208	—
RH^2	RO^3	VI		O = 16·00	S = 32·06		Se = 79	Te = 127	—	—	—
RH	R^2O^7	VII		F = 19·0	Cl = 35·45		Br = 79·95	I = 127	—	—	—
R	R	0	He = 4·0	Ne = 19·9	Ar = 38		Kr = 81·8	Xe = 128	—	—	—
							Elements of uneven series				

the periodic law, the distribution of the elements according to groups and series in the table on page 26 is perhaps clearer.

Here x and y stand for two unknown elements having atomic weights less than that of hydrogen, whose discovery I now look for.

A reference to the above remarks on the argon group of elements shows first of all that such a zero group as they correspond to could not possibly have been foreseen under the conditions of chemical knowledge at the time of the discovery of the periodic law in 1869; and, although I had a vague notion that hydrogen might be preceded by some elements of less atomic weights, I dared not put forward such a proposal, because it was purely conjectural, and I feared to injure the first impression of the periodic law by its introduction. Moreover, in those days the question of the ether did not awaken much interest, for electrical phenomena were not then ascribed to its agency, and it is this that now gives such importance to the ether. But at the present time, when there can be no doubt that the hydrogen group is preceded by the zero group composed of elements of less atomic weights, it seems to me impossible to deny the existence of elements lighter than hydrogen.

Let us first consider the element in the first

Series	Zero Group	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII			
0	x											
1	y	Hydrogen H=1·008										
2	Helium He=4·0	Lithium Li=7·03	Beryllium Be=9·1	Boron B=11·0	Carbon C=12·0	Nitrogen N=14·04	Oxygen O=16·00	Fluorine F=19·0				
3	Neon Ne=19·9	Sodium Na=23·05	Magnesium Mg=24·1	Aluminium Al=27·0	Silicon Si=28·4	Phosphorus P=31·0	Sulphur S=32·06	Chlorine Cl=35·45				
4	Argon Ar=38	Potassium K=39·1	Calcium Ca=40·1	Scandium Sc=44·1	Titanium Ti=48·1	Vanadium V=51·4	Chromium Cr=52·1	Manganese Ma=55·0	Iron Fe=55·9	Cobalt Co=59	Nickel Ni=59	(Cu)
5		Copper Cu=63·6	Zinc Zn=65·4	Gallium Ga=70·0	Germanium Ge=72·3	Arsenic As=75·0	Selenium Se=79	Bromine Br=79·95				
6	Krypton Kr=81·8	Rubidium Rb=85·4	Strontium Sr=87·6	Yttrium Y=89·0	Zirconium Zr=90·6	Niobium Nb=94·0	Molybdenum Mo=96·0	—	Ruthenium Ru=101·7	Rhodium Rh=103·0	Palladium Pd=106·5	(Ag)
7		Silver Ag=107·9	Cadmium Cd=112·4	Indium In=114·0	Tin Sn=119·0	Antimony Sb=120·0	Tellurium Te=127	Iodine I=127				
8	Xenon Xe=128	Cæsium Cs=132·9	Barium Ba=137·4	Lanthanum La=139	Cerium Ce=140	—	—	—	—	—	—	(—)
9		—	—	—	—	—	—	—				
10	—	—	—	Ytterbium Yb=173	—	Tantalum Ta=183	Tungsten W=184	—	Osmium Os=191	Iridium Ir=193	Platinum Pt=194·9	(Au)
11		Gold Au=197·2	Mercury Hg=200·0	Thallium Tl=204·1	Lead Pb=206·9	Bismuth Bi=208	—	—				
12		—	Radium Rd=224	—	Thorium Th=232	—	Uranium U=239	—				

series of the zero group. It is designated by *y*. It will evidently exhibit all the fundamental properties of the argon gases. But first we must have an approximate idea of its atomic weight. To do this, let us consider the ratio of the atomic weights of two elements belonging to the same group in neighbouring series. Starting with Ce = 140 and Sn = 119 (here the ratio is 1·18), this ratio, in passing to the lower groups and series, increases constantly and fairly uniformly as the atomic weights of the elements under comparison decrease. But we will limit our calculation to the first and second series, starting with Cl = 35·45 ; for (1) we are exclusively concerned with the lightest elements, (2) the ratio of the atomic weights is more accurate for these elements, and (3) the small periods of the typical elements (which should include the elements lighter than hydrogen) terminate with chlorine. As the atomic weight of chlorine is 35·45 and that of fluorine 19·0, the ratio Cl : F = 35·4 : 19·0 = 1·86 ; so also we find :

Group VII	Cl : F	= 1·86
VI	S : O	= 2·00
V	P : N	= 2·21
IV	Si : C	= 2·37
III	Al : B	= 2·45
II	Mg : Be	= 2·67
I	Na : Li	= 3·28
0	Ne : He	= 4·98

This proves that the ratio in the given series distinctly and progressively increases in passing from the higher to the lower groups; and, moreover, that it varies most rapidly between the first and zero groups. It follows therefore that the ratio He : y will be considerably greater than the ratio Li : H which is 6·97, so that the ratio He : y will be at least 10 and probably even greater. Hence, as the atomic weight He = 4·0, the atomic weight of y will be not greater than $\frac{4{\cdot}0}{10} = 0{\cdot}4$ and probably less. Such an analogue of helium may perhaps be found in coronium, whose spectrum, clearly visible in the solar corona above (that is, further from the sun than) that of hydrogen, is simple like that of helium, which seems to indicate that it belongs to a gas resembling helium, which was also predicted from its spectrum by Lockyer. Young and Harkness independently observed the spectrum of this unknown element during the solar eclipse of 1869. It is characterised by a bright-green line of wave length 531·7$\mu\mu$, while helium is characterised by a yellow line, 587$\mu\mu$. Nasini, Anderlini, and Salvadori think that they discovered traces of coronium in their observations on the spectra of volcanic gases (1893). And as the lines of

coronium were also observed, even at distances many times the radius of the sun above its atmosphere and protuberances, where the hydrogen lines are no longer visible, it is evident that coronium should have a less density and atomic weight than hydrogen. Moreover, as the ratio of the specific heats (at a constant pressure and for a constant volume) of helium, argon, and their analogues gives reason for thinking that their molecules (*i.e.* the amount of matter occupying, according to Avogadro-Gerhardt's law, a volume equal to the volume of two parts by weight of hydrogen) contain only one atom (like mercury, cadmium, and most metals), it follows that, if 0·4 be the greatest atomic weight of the element *y*, its density referred to hydrogen should be less than 0·2. Consequently the molecules of this gas will, according to the kinetic theory of gases, move 2·24 times faster than those of hydrogen, and if, as Stoney (1894–1898) and Rostovsky (1899) endeavour to prove, the progressive motion of the molecules of hydrogen and helium be such that they can leap out of the sphere of the earth's attraction, then a gas whose density is at least five times less than that of hydrogen could certainly only exist in the atmosphere of a body having as great a mass as the sun.

However, this *y*—coronium or some other gas with a density about 0·2—cannot possibly be ether, its density being too great. It wanders, perhaps for ages, in the regions of space, breaks from the shackles of the earth and again comes within its sphere, but still it cannot escape from the regions of the sun's attraction, and there are many heavenly bodies of greater mass than the sun. But the atoms of ether must be of another kind; they must be capable of overcoming even the sun's attraction, of freely permeating all space, and of penetrating everything and everywhere. The element *y*, however, is necessary for us to be able to mentally realise the lightest and therefore swiftest element *x*, which I consider may be looked upon as the ether.

We have seen that, besides the ordinary groups of the chemically active elements, a zero group of chemically inactive elements must now be recognised for helium, argon, and their analogues. Thanks to Ramsay's exemplary researches, these elements are now tangible realities, authentic gases foreign to chemical association, that is, distinguished by their specific property of not being chemically attracted to each other or to other atoms even at infinitely small distances, and yet having weight, that is, subject to the

laws of attraction of mechanics, which has nothing in common with chemical attraction. There is some hope that gravity may in some way or another be explained by means of pressure or impact acting from all sides, but chemical attraction, which only acts at infinitely small distances, will long remain an incomprehensible problem. The problem of the ether is more or less closely connected with that of gravity, and gains in simplicity when all question of the chemical attraction of the atoms of ether is excluded, and this is accomplished by placing it in the zero group. But if the series of the elements begins with series I containing hydrogen, the zero group has no place for an element lighter than *y*, like ether. I therefore add a zero series, besides a zero group, to the periodic system, and place the element *x* in this zero series, regarding it (1) as the lightest of all the elements both in density and atomic weight; (2) as the most mobile gas; (3) as the element least prone to enter into combination with other atoms, and (4) as an all-permeating and penetrating substance. Of course, this is a hypothesis, but it is not one constructed for purely 'working' ends, but simply from a desire to extend the real periodic system of the known elements to the

confines or limits of the lowest dimensions of atoms, which I cannot and will not regard in the light of a simple nullity called mass.

Being unable to conceive the formation of the known elements from hydrogen, I can neither regard them as being formed from the element x, although it is the lightest of all the elements. I cannot admit this, not only because no fact points to the possibility of the transformation of one element into another, but chiefly because I do not see that such an admission would in any way facilitate or simplify our understanding of the substances and phenomena of nature. And when I am told that the doctrine of unity in the material of which the elements are built up responds to an aspiration for unity in all things, I can only reply that at the root of all things a distinction must be made between matter, force, and mind; that it is simpler to admit the germs of individuality in the material elements than elsewhere, and that no general relation is possible between things unless they have some individual character resident in them. In a word, I see no object in following the doctrine of the unity of matter, while I clearly see the necessity of recognising the unity of the substance of the ether and of realising a conception of it, as the utter-

most limit of that process by which all the other atoms of the elements were formed and by which all substances were formed from these atoms. To me this kind of unity is far more real than any conception of the formation of the elements from a single primary matter. Neither gravity nor any of the problems of energy can be rightly understood without a real conception of the ether as a universal medium transmitting energy at a distance. Moreover, a real conception of ether cannot be obtained without recognising its chemical nature as an elementary substance, and in these days no elementary substance is conceivable which is not subject to the periodic law.

I will therefore, in conclusion, endeavour to show what consequences should follow from the above conception of the ether, from an experimental or realistic point of view, even should it never be possible to isolate or combine or in any way grasp this substance.

Although it was possible to approximately determine the atomic weight of the element y on the basis of that of helium, this cannot be repeated for the element x, because it lies at the frontier or limit, about the zero point of the atomic weights. Moreover, the analogues of helium

cannot serve as a basis owing to the uncertainty of their numerical data. However, if the ratio of the atomic weights be Xe : Kr=1·56 : 1; Kr : Ar= 2·15 : 1; and Ar : He=9·5 : 1, we find that He : x = 23·6 : 1; or if He=4·0, that the atomic weight of x=0·17. This must be considered the maximum possible value. Most probably the atomic weight of x is far less, for the following reasons. If the gas in question be an analogue of helium, its molecule will contain one atom, and therefore its density, referred to that of hydrogen, must be about half its atomic weight or $\frac{x}{2}$, where x is the atomic weight. In order to be able to permeate throughout all space, its density must be so small, compared with that of hydrogen, that its molecular motion would allow it to overcome the attraction, not only of the earth and sun, but also of all the stars, as otherwise it would accumulate about the largest mass and not fill all space. The velocity of the molecular motion of a gas by which the gaseous pressure is determined—by the number of impinging particles and their *vis viva*—is calculated according to the kinetic theory of gases, by an expression containing a constant divided by the square root of the density of the gas and multiplied by the

square root of $(1+at)$ which expresses the expansion of the gas by heat. In the case of hydrogen (density = 1) at $t=0°$, the mean velocity of the particles, calculated on the basis that a litre of hydrogen at 0° and 760 m.m. weighs about 0·09 grms., is 1843 mètres a second, that of oxygen being 461 mètres, for its density is 16 times that of hydrogen, *i.e.* $v = \frac{1843}{4} = 461$. Thus the velocity increases as the density becomes less and as the temperature becomes greater, but does not depend upon the number of molecules in a given volume ; and if our gas have an atomic weight x and density (referred to hydrogen) $\frac{x}{2}$, then the velocity of its molecules will be :

$$v = 1843\sqrt{\frac{2(1+at)}{x}} \quad . \quad . \quad . \quad (1)$$

In this expression x is the unknown quantity, to find which we must know t and v, or the velocity required by the particles to escape from the sphere of the earth's, sun's, and stars' attraction, like the projectile in Jules Verne's 'Voyage to the Moon.'

As regards the temperature of space, this can only be regarded as the absolute zero by those who deny the material nature of the ether, for

temperature in a perfect vacuum or in space devoid of matter is an absurdity, and a solid such as an aerolite or thermometer introduced into such space would alter the temperature, not by contact with the surrounding medium, but solely by radiation. But if space be filled with the substance of ether, it not only may, but must, have its own temperature, which evidently cannot be absolute zero. Many methods have been tried to determine this temperature, but it is unnecessary to discuss them here. Suffice it to say that no one has found it less than $-150°$ or above $-40°$; as a rule, the limits are taken as $-100°$ and $-60°$. It is hopeless to expect any definite or exact data on this subject, and probably the temperature varies in different localities owing to radiation being different in different parts of space. Moreover, the value of t between $-100°$ and $-60°$ has hardly any significance in an approximate evaluation of x, as only the maximum value of x can be calculated by the expression (I); for there can be no question of any exact value, all that is required being to obtain an idea of the order in which x stands among the elements. We therefore take the mean temperature $t=-80$; then if $a=0{\cdot}000367$,

$$v=\frac{2191}{\sqrt{x}} \text{ or } x=\frac{4800000}{v^2} \quad . \quad . \quad \text{(II)}$$

where x is the atomic weight of the gaseous element required, referred to hydrogen, and v the velocity of motion of its particles at $-80°$ in mètres per second.

This velocity must now be determined. We know that a body thrown up in the air falls back to the earth, and in so doing describes a parabola. The height of its flight increases as its initial velocity is made greater, and it is evident that this velocity might be such that the body would pass beyond the sphere of the earth's attraction, and fall on some other heavenly body, or rotate about the earth as a satellite by virtue of the laws of gravitation. It has been calculated that to do this the velocity of the body must exceed the square root of double the mass of the attracting body divided by the distance from its centre of gravity to the point at which the velocity is to be determined. The mass of the earth is calculated in absolute units from the mean radius of the earth (= 6,373,000 mètres) and the mean attraction of gravity at the surface of the earth (= 9·807 mètres), for the attraction of gravity is equal to the mass divided by the square of the distance (in this instance, the square of the earth's radius), and therefore the mass of the earth = 398.10^{12}, and the velocity

sought for must therefore exceed 11,190 mètres a second. Hence, according to formula II., the atomic weight of such a gas must be less than 0·038 to enable it to escape freely from the earth's atmosphere into space. All gases of greater atomic weight, not only hydrogen and helium, but even the gas *y* (coronium ?), will remain in the earth's atmosphere.

The mass of the sun is approximately 325,000, if that of the earth be taken as unity. Hence the absolute magnitude of the sun's mass will be nearly 129.10^{18}. The radius of the sun is 109·5 times greater than that of the earth, *i.e.* nearly 698.10^{16} mètres. Hence only bodies or particles having a velocity of not less than $\sqrt{\frac{2.129.10^{18}}{698.10^{16}}}$ or about 608,300 mètres a second, could escape from the surface of the sun. According to formula (II), the atomic weight of a gas *x* having such a velocity will not be greater than 0·000013, and its density will be half this figure. Hence the atomic weight and density of such a gas which, like the ether, permeates space, must at all events be less than this figure. This is inevitable because there are stars of greater mass than the sun. This has been proved by researches made on the double stars.

The most exact data we now possess concern Sirius, whose total mass (including that of its satellites) is 3·24 times that of the sun. To determine this, it was necessary to investigate not only the relative motion of both stars, but also the parallax of this system. In the case of Sirius it was possible to determine the ratio of the masses of the two stars. This was found to be 2·05, so that the mass of one star is 2·20, and that of the other 1·04, times that of the sun. In the following cases, only the total mass of the two twin stars was determined relative to that of the sun :

α Centauri	2·0
70 Ophiuchi	1·6
μ Cassiopeiæ	0·52
61 Cygni	0·34
γ Leonis	5·8
γ Virginis	32·70

The mass of β Persei with its satellites is 0·67 times that of the sun, that of the star being twice that of its satellite. The triple star 40 Eridium has a mass 1·1 times that of the sun, the mass of the brightest star being 2·37 times that of the other two.

It appears, therefore, that although there are some stars which are greater, and some which are less, still the mass of the sun is nearly the

average of that of the other stars. For our purpose we need only consider the stars of much greater mass than the sun. That of the double star γ Virginis has a common mass about 33 times that of the sun. There is no reason for thinking that this is the maximum, and it will therefore be safer to infer that there may be stars whose mass exceeds 50 times that of the sun, but I do not think it likely that a larger mass than this is in the nature of things. To complete our calculation it is also necessary to know the radius of the stars, about which we have no direct data. However, the composition and temperature of the stars may give a clue. Spectrum analysis proves that the terrestrial chemical elements occur in the most distant heavenly bodies, and from analogy there seems no doubt that the general mass composition of these bodies is very similar in all cases ; that is to say, that they are composed of a dense core surrounded by a less dense crust and an atmosphere which becomes gradually rarefied. Thus the composition of the stars probably differs but little from that of the sun. And the density is determined by the composition, temperature, and pressure. Only at the core can the density differ much from that of the sun, but this cannot greatly affect

the average density. Neither can the temperature of the stars differ greatly from that of the sun. Moreover, a rise of temperature would tend to increase the diameter of the star, and this would decrease the value of the velocity required by the gaseous particles to escape from the sphere of attraction. It appears, therefore, that for the purposes of our calculation the average density of the large stars may be taken as nearly that of the sun, and therefore that the radius of a star whose mass is n times that of the sun will be $\sqrt[3]{n}$ times the radius of the sun. We now have all the data necessary for calculating the velocity required by gaseous particles to escape from the sphere of attraction of a star 50 times greater than the sun.

Its mass is $50.129.10^{18}$ or nearly 65.10^{29}, and its radius nearly $698.10^{6}\sqrt[3]{50}$ or 26.10^{8}. Hence the velocity required will be nearly :

$$\sqrt{\frac{2.65 \times 10^{20}}{26 \times 10^{8}}} = 2{,}240{,}000 \text{ mètres per second,}$$

or 2,240 kilomètres per second.

The great magnitude of this velocity, v, and its proximity to that of light (300,000,000 mètres a second) provoke the following inquiry. How much must the mass of a heavenly body

exceed that of the sun in order to retain on its surface particles endowed with a velocity of 3.10^8 mètres per second, if its mean density were equal to that of the sun? This may be calculated from the fact that if the mean density of the two luminaries be equal, the velocities of bodies able to escape into space from the spheres of attraction will stand in the ratio of the cube roots of their masses, and therefore a luminary from whose surface particles endowed with a velocity of 300,000,000 mètres per second could escape must have a mass 120,000,000 times that of the sun, for only particles having a velocity of 608,000 mètres a second can escape from the sun, and this stands to 300,000,000 in the ratio 1 : 493, and the cube of 493 is nearly 120,000,000.

But, so far we have no reason for admitting the existence of such a huge body, and therefore it seems to me that the velocity of the particles of our gas (ether) must, in order to permeate space, be greater than 2,240,000 mètres a second and probably less than 300,000,000 mètres a second.

Hence the atomic weight of x as the lightest elementary gas, permeating space and performing the part of the ether, must be within the limits (formula II) of 0·000,000,96 and 0·000,000,000,053, if that of H = 1.

I think it is impossible, under the present conditions of our scientific knowledge, to admit the latter value, because it would in some measure answer to a revival of the emission theory of light, and I consider that the majority of phenomena are sufficiently explained by the fact that *the particles and atoms of the lightest element x capable of moving freely everywhere throughout the universe have an atomic weight nearly one millionth that of hydrogen, and travel with a velocity of about* 2,250 *kilomètres per second.*

When I was making these calculations, my friend Professor Dewar sent me his presidential address to the Belfast meeting of the British Association. In it he expresses the thought that the highest regions of the atmosphere, which are the seat of the aurora borealis, must be considered to be the province of hydrogen and of the argon analogues. This is only a few steps from the yet more distant regions of space, and from the necessity of recognising the existence of a still lighter gas capable of permeating and filling space and thus giving a tangible reality to the conception of the ether.

In conceiving of the ether as a gas endowed with the above properties, and belonging to the zero group of elements, I desired before all to

extract from the periodic law that which it was able to give and to tangibly explain the materiality and universal presence of an ethereal substance throughout nature, and also to explain its faculty of permeating all substances, gaseous, liquid, and solid. The atoms of even the lighter elements forming the ordinary substances being several million times heavier than those of ether, they are not likely to be greatly influenced in their mutual relations by its presence.

Of course there are still many problems to be solved, but I think the majority are unfathomable, and I have no intention of raising them here or of trying to solve those which appear capable of being solved. My only purpose has been to state my opinion on a subject about which I know many are thinking and some are beginning to speak.

Without going into a further development of our subject, I should like to acquaint the reader with some, at first sight, auxiliary circumstances which guided my thoughts and led me to publish my opinions. These consist of a series of recently discovered physico-chemical phenomena which are not subject to the ordinary doctrines of science, and have caused many to return to the emission theory of light, or to

accept the, to me, vague hypothesis of electrons, without trying to explain to the utmost the familiar conception of an ethereal medium transmitting luminous vibrations, &c. This more especially refers to radio-active phenomena.

I need not describe these most remarkable phenomena, assuming that the reader is more or less acquainted with them ; and will only mention that a perusal of the literature of the subject, and what I saw in M. Becquerel's laboratory and heard from him and Monsieur and Madame Curie, gave me the impression of some peculiar state proper chiefly (but not exclusively, just as magnetism is chiefly, but not exclusively, the property of iron and cobalt) to uranium and the thorium compounds.

As uranium and thorium, and also radium, judging from Madame Curie's researches (1902), have the highest atomic weights (U=239, Th=232, and Rd=224) among the elements, they may be looked upon as suns, endowed with the highest degree of that individualised attractive capacity, a mean between gravity and chemical affinity, which is seen in the absorption of gases, solution, &c. By conceiving the substance of the ether as the lightest of gases, *x*, deprived, like helium and argon, of the power to form stable

definite compounds, it need not be imagined that this gas is deprived of the faculty of, as it were, dissolving in or accumulating about large centres of attraction like the sun among heavenly bodies, or uranium and thorium in the world of atoms. As a matter of fact, direct experiment proves that helium and argon are able to dissolve in liquids, and, moreover, to individualise this faculty according to either their own nature or that of the liquid and according to the temperature. If the ether is a gas, x, it must naturally accumulate from all parts of the universe towards the medium or mass of the sun, just as the gases of the atmosphere accumulate in a drop of water. And the lightest of gases, x, will also accumulate about the heaviest atoms of uranium and thorium, and perhaps change its form of motion like a gas dissolved in a liquid. This will not be a definite act of combination, determined by a conformable harmonious motion, like the motion of a planet and its satellites, but an embryo of such a motion, resembling that of a comet in the region of heavenly individualisations, and it may be looked for sooner in the region of the heaviest atoms of uranium and thorium than in those of the lighter elements, just as a comet falling from space into the planetary system revolves

round the sun and then once more escapes into space. If such a special accumulation of ether atoms about the molecules of uranium and thorium be admissible, they might be expected to exhibit peculiar phenomena, determined by the emission of a portion of this ether held by particles of normal mean velocity and by new ether entering into the sphere of attraction. It seems to me that the optical and photo-radiant phenomena, not to mention the loss of electrical charges, indicate a material flow of something which has not been weighed, and it appears to me that they might be understood in this manner, for peculiar forms of the entrance and egress of ether atoms should be accompanied by such disturbances in the ethereal medium as give the phenomena of light. Monsieur and Madame Curie showed me the following experiment, for instance. Two small flasks were connected together by a lateral tube fused into their necks, and having a stop-cock in the middle. The cock being closed, a solution of the radio-active substance was poured into one of the flasks, while a gelatinous white precipitate of sulphide of zinc, shaken up in water, was placed in the other flask. Then both flasks were closed. So long as the cock between the

flasks remains closed, nothing is visible in the dark; but directly it is opened, the sulphide of zinc becomes brilliantly fluorescent and continues so as long as the tube connecting the flasks remains open. This experiment gives the impression of an emissive flow of something material from the radio-active substance, and, in a sense, seems comprehensible if we assume that a peculiar rarefied ether gas, capable of exciting luminous vibrations, enters and passes off from the radio-active substance. Just as any kind of motion may be set up in a gas, not only by a solid piston, but also by the motion of another portion of the same gas, so also the phenomenon of light, *i.e.* a certain transverse vibration of ether, may be produced not only by the molecular motion of particles of other bodies (by heating them or otherwise) bringing the ether from its state of mobile equilibrium, but also by a certain change in the motion of the ether atoms themselves; *i.e.* by their destroying their own equilibrium which may be caused in the case of the radio-active bodies by the massiveness of the atoms of uranium and thorium, just as the luminosity of the sun may be, I think, due to its great mass being able to accumulate ether in far larger quantities than the planets, &c. I

think that the radio-luminous phenomena, *i.e.* such as proceed at right angles to the ray of the vibration of the ether medium, consisting of minute atoms in rapid motion, are, as a matter of fact, more complex than has hitherto been thought, chiefly owing to the fact that the velocity of the ether atoms is not very much less (130 times) than that of the propagation of their transverse vibrations. This at all events was the impression I acquired from the radio-active phenomena I saw, and I do not conceal it, although I consider it very difficult to form any opinion on this still dim province of the phenomena of light.

In conclusion, I may mention another class of phenomena, which led me to this conception of the ether. Dewar, about 1894, in his researches on the phenomena proceeding at low temperatures, observed that the phosphorescence of many substances, and especially of paraffin, becomes more intense at the temperature of liquid air (between $-181°$ and $-193°$). Now, it appears to me that this is due to the fact that paraffin and such like substances have a great capacity for condensing the atoms of ether at very low temperatures. In other words, that the solubility (absorption) of the ether in some bodies increases

in extreme cold. They therefore become more phosphorescent, for the vibrations of light are then set up in the phosphorescent substances, not only by their own atoms (having the property of illumination at their surface, of passing into a state of peculiar tension, which causes, when the act of illumination ceases, the ether to vibrate), but also by the atoms of ether which condense in these bodies and set up a rapid state of interchange with the surrounding medium.

It seems to me that this conception of ether, as a peculiar all-permeating gas, gives a means, if not of analysing such phenomena, at all events of understanding their possibility. I do not regard my imperfect endeavour to explain the nature of ether from a chemical point of view as more than the expression of a series of thoughts which have arisen in my mind, and which I have given vent to solely from a desire that these thoughts, being suggested by facts, should not be utterly lost. Most probably similar thoughts have come to many, but unless they are enunciated they often pass away without being further developed. If they contain a particle of that natural truth which we all seek, my effort will not have been in vain; it

may then be worked out, embodied and corrected, and if my conception be proved false in its basis, it will prevent others from repeating it. I know of no other way for slow and steady progress. And even if it be found impossible to recognise in the ether the properties of the lightest, most mobile, and chemically inactive gas, still, if we keep to the realism of science, we cannot deny its substantiality, and this requires a search for its chemical nature. My effort is no more than a tentative answer to this primary question, and its one object is to bring this question to the fore.

October 1902.

PRINTED BY
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