SCIENCE

A WEEKLY JOURNAL DEVOTED TO THE ADVANCEMENT OF SCIENCE, PUBLISHING THE OFFICIAL NOTICES AND PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

FRIDAY, JUNE 26, 1903.

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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

*MODERN VIEWS ON MATTER: THE REALIZATION OF A DREAM.**

FOR nearly a century men who devote themselves to science have been dreaming of atoms, molecules, ultramundane particles, and speculating as to the origin of matter; and now to-day they have got so far as to admit the possibility of resolving the chemical elements into simpler forms of matter, or even of refining them altogether away into ethereal vibrations or electrical energy.

This dream has been essentially a British dream, and we have become speculative and imaginative to an audacious extent, almost belying our character of a purely practical nation. The notion of impenetrable mysteries has been dismissed. A mystery is a thing to be solved—'and man alone can master the impossible.' There has been a vivid new start. Our physicists have remodeled their views as to the constitution of matter and as to the complexity if not the actual decomposability of the chemical elements. To show how far we have been propelled on the strange new road, how dazzling are the wonders that waylay the researcher, we have but to recall—matter in a fourth state, the genesis of the elements, the dissociation of

* An address delivered before the Congress of Applied Chemistry at Berlin, June 5, 1903, from proof under correction.

the chemical elements, the existence of bodies smaller than atoms, the atomic nature of electricity, the perception of electrons, not to mention other dawning marvels far removed from the lines of thought usually associated with English chemistry.

The earliest definite suggestion in the last century of the possible compound nature of the metals occurs in a lecture delivered in 1809* by Sir Humphry Davy at the Royal Institution. In that memorable lecture he speculated on the existence of some substance common to all the elements, and he averred that "If such generalizations should be supported by facts, a new, a simple and a grand philosophy would be the result. From the combination of different quantities of two or three species of ponderable matter we might conceive all the diversity of material substances to owe their constitution."

Again, in 1811, he said:† "It will be useless to speculate upon the consequences of such an advancement in chemistry as that of the decomposition and composition of the metals. * * * It is the duty of a chemist to be bold in pursuit. He must not consider things as impracticable merely because they have not yet been effected. He must not regard them as unreasonable because they do not coincide with popular opinion. He must recollect how contrary knowledge sometimes is to what appears to be experience. * * * To inquire whether the metals be capable of being decomposed and composed is a grand object of true philosophy."

Davy first used the term 'radiant matter' about 1809, but chiefly in connection with what is now called radiation. He also used the term in another sense, and the following passage‡ in its clear forecast is prophetic of the modern electron: 'If particles of gases were made to move in free space with an almost infinitely great velocity—*i. e.,* to become radiant matter—they might produce the different species of rays, so distinguished by their peculiar effects.'

In his lectures at the Royal Institution, in 1816, 'On the General Properties of Matter,' another prescient chemist, Faraday, used similar terms when he said: "If we conceive a change as far beyond vaporization as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes rise, we shall, perhaps, if we can form any conception at all, not fall far short of radiant matter; and as in the last conversion many qualities were lost, so here also many more would disappear." again, in one of his early lectures he strikes a forward note: "At present we begin to feel impatient, and to wish for a new state of chemical elements. To decompose the metals, to reform them, and to realize the once absurd notion of transmutation, are the problems now given to the chemist for solution."

But Faraday was always remarkable for the boldness and originality with which he regarded generally accepted theories. In 1844 he said, "The view that physical chemistry necessarily takes of atoms is now very large and complicated; first many elementary atoms—next compound and complicated atoms. System within system, like the starry heavens, *may be right* —but may *be all wrong.*"

A year later Faraday startled the world by a discovery to which he gave the title 'On the Magnetization of Light and the Illumination of the Magnetic Lines of Force.' For fifty years this title was misunderstood and was attributed to enthusiasm or confused ideas. But to-day

* 'Works of Sir Humphry Davy,' Vol. VIII., p. 325.

† *Loc. cit.,* Vol. VIII., p. 330.

‡ *Loc. cit.,* Vol. VIII., p. 349.

we begin to see the full significance of the Faraday dream.

In 1879, in a lecture I delivered before the British Association* at Sheffield, it fell to my lot to revive 'Radiant Matter.' I advanced the theory that in the phenomena of the vacuum tube at high exhaustions the particles constituting the cathode stream are not solid, nor liquid, nor gaseous, do not consist of atoms propelled through the tube and causing luminous, mechanic or electric phenomena where they strike, 'but that they consist of something much smaller than the atom—fragments of matter, ultra-atomic corpuscles, minute things, very much smaller, very much lighter than atoms—things which appear to be the foundation stones of which atoms are composed.'†

I further demonstrated that the physical properties of radiant matter are common to all matter at this low density—'Whether the gas originally under experiment be hydrogen, carbon dioxide or atmospheric air, the phenomena of phosphorescence, shadows, magnetic deflection, etc., are identical.' Here are my words, written nearly a quarter of a century ago: "We have actually touched the borderland where matter and force seem to merge into one another‡—the shadowy realm between the known and unknown. I venture to think that the greatest scientific problems of the future will find their solution in this borderland, and even beyond; here, it seems to me, lie ultimate realities, subtle, far-reaching, wonderful."

It was not till 1881 that J. J. Thomson established the basis of the electrodynamic theory. In a very remarkable memoir in the *Philosophical Magazine* he explained the phosphorescence of glass under the influence of the cathode stream by the nearly abrupt changes in the magnetic field arising from the sudden stoppage of the cathode particles.

The now generally accepted view that our chemical elements have been formed from one primordial substance was advocated in 1888 by me when president of the Chemical Society,* in connection with a theory of the genesis of the elements. I spoke of 'an infinite number of immeasurably small ultimate—or, rather, ultimatissimate—particles gradually accreting out of the formless mist, and moving with inconceivable velocity in all directions.'

Pondering on some of the properties of the rare elements, I strove to show that the elementary atoms themselves might not be the same now as when first generated—that the primary motions which constitute the existence of the atom might slowly be changing, and even the secondary motions which produce all the effects we can observe—heat, chemic, electric and so forth—might in a slight degree be affected; and I showed the probability that the atoms of the chemical elements were not eternal in existence, but shared with the rest of creation the attributes of decay and death.

The same idea was expanded at a lecture I delivered at the Royal Institution in 1887, when it was suggested that the atomic weights were not invariable quantities.

I might quote Mr. Herbert Spencer, Sir Benjamin Brodie, Professor Graham, Sir George Stokes, Sir William Thomson (now Lord Kelvin), Sir Norman Lockyer, Dr. Gladstone and many other English *savans* to show that the notion—not necessarily of the decomposability but at any rate of the complexity of our supposed elements

* 'British Association Reports,' Sheffield Meeting, 1879. *Chemical News*, Vol. XL., p. 91. *Phil. Trans. Roy. Soc.*, 1879, Part I., p. 585. *Proc. Roy. Soc.*, 1880, No. 205, p. 469.

† Sir O. Lodge, *Nature*, Vol. LXVII., p. 451.

‡ 'Matter is but a mode of motion' (*Proc Roy. Soc.*, No. 205, p. 472).

* Pres. Address to Chem. Soc., March 28, 1888.

has long been 'in the air' of science, waiting to take more definite development. Our minds are gradually getting accustomed to the idea of the genesis of the elements, and many of us are straining for the first glimpse of the resolution of the chemical atom. We are eager to enter the portal of the mysterious region too readily ticketed 'Unknown and Unknowable.'

Another phase of the dream now demands attention. I come to the earlier glimpses of the electric theory of matter.

Passing over the vague speculations of Faraday and the more positive speculations of Sir William Thomson (now Lord Kelvin), one of the earliest definite statements of this theory is given in an article in the *Fortnightly Review* for June, 1875, by W. K. Clifford—a man who in common with other pioneers shared that 'noblest misfortune of being born before his time.' 'There is great reason to believe,' said Clifford, 'that every material atom carries upon it a small electric current, *if it does not wholly consist of this current.*'

In 1886 when president of the Chemical Section of the British Association, in a speculation on the origin of matter, I drew a picture of the gradual formation of the chemical elements by the workings of three forms of energy—electricity, chemism and temperature—on the 'formless mist' (protyle*), wherein all matter was in the preatomic state—potential rather than actual. In this scheme the chemical elements owe their stability to being the outcome of a struggle for existence—a Darwinian development by chemical evolution—a survival of the most stable. Those of lowest atomic weight would first be formed, then those of intermediate weight, and finally the elements having the highest atomic weights, such as thorium and uranium. I spoke of the 'dissociation point' of the elements. "What comes after uranium?" I asked. And I answered back, "The result of the next step will be * * * the formation of * * * compounds the dissociation of which is not beyond the powers of our terrestrial sources of heat." A A dream less than twenty years ago, but a dream which daily draws nearer to entire and vivid fulfilment. I will presently show you that radium, the next after uranium, does actually and spontaneously dissociate.

* We require a word, analogous to protoplasm, to express the idea of the original primal matter existing before the evolution of the chemical elements. The word I venture to use is composed of πρό (*earlier than*) and ὕλη (*the stuff of which things are made*).

The idea of units or atoms of electricity —an idea hitherto floating intangibly like helium in the sun—can now be brought to earth and submitted to the test of experiment.* Faraday, W. Weber, Laurentz,

* "The equivalent weights of bodies are simply those quantities of them which contain equal quantities of electricity; * * * it being the electricity which *determines* the equivalent number, *because* it determines the combining force. Or, if we adopt the atomic theory or phraseology, then the atoms of bodies which are equivalents to each other in their ordinary chemical action, have equal quantities of electricity naturally associated with them." Faraday's 'Experimental Researches in Electricity' par. 869, January, 1834.

"This definite quantity of electricity we shall call the molecular charge. If it were known it would be the most natural unit of electricity." Clerk Maxwell's 'Treatise on Electricity and Magnetism,' first edition, Vol. I., 1873, p. 311.

"Nature presents us with a single definite quantity of electricity. * * * For each chemical bond which is ruptured within an electrolyte a certain quantity of electricity traverses the electrolyte, which is the same in all cases." G. Johnstone Stoney, 'On the Physical Units of Nature,' British Association Meeting, Section A, 1874.

"The same definite quantity of either positive or negative electricity moves always with each univalent ion, or with every unit of affinity of a multivalent ion." Helmholtz, Faraday Lecture, 1881.

Gauss, Zöllner, Hertz, Helmholtz Johnstone Stoney, Sir Oliver Lodge, have all contributed to develop the idea—originally due to Weber—which took concrete form when Stoney showed that Faraday's law of electrolysis involved the existence of a definite charge of electricity associated with the ions of matter. This definite charge he called an electron. It was not till some time after the name had been given that electrons were found to be capable of existing separately.

In 1891, in my inaugural address as president of the Institution of Electrical Engineers,* I showed that the stream of cathode rays near the negative pole was always negatively electrified, the other contents of the tube being positively electrified, and I explained that 'the division of the molecule into groups of electro-positive and electro-negative atoms is necessary for a consistent explanation of the genesis of the elements.' In a vacuum tube the negative pole is the entrance and the positive pole the exit for electrons. Falling on a phosphorescent body, yttria, for instance, —a collection of Hertz molecular resonators—the electrons excite vibrations of, say, 550 billion times a second, producing ether waves of the approximate length of 5.75 ten-millionths of a millimeter, and occasioning in the eye the sensation of citron-colored light. If, however, the electrons dash against a heavy metal or other body which will not phosphoresce, they produce ether waves of a far higher frequency than light, and are not continuous vibrations, but, according to Sir George Stokes, simple shocks or solitary impulses; more like discordant shouts as compared with musical notes.

"Every monad atom has associated with it a certain definite quantity of electricity; every dyad has twice this quantity associated with it; every triad three times as much, and so on." O. Lodge, 'On Electrolysis,' *British Association Report*, 1885.

* 'Electricity in Transitu: from Plenum to Vacuum,' *Journ. Inst Electrical Engineers*, Vol. XX., p. 10, January 15, 1891.

During that address an experiment was shown which went far to prove the dissociation of silver into electrons and positive atoms.* A silver pole was used, and near it in front was a sheet of mica with a hole in its center. The vacuum was very high, and when the poles were connected with the coil, the silver being negative, electrons shot from it in all directions, and passing through the hole in the mica screen, formed a bright phosphorescent patch on the opposite side of the bulb. The action of the coil was continued for some hours, to volatilize a certain portion of the silver. Silver was seen to be deposited on the mica screen only in the immediate neighborhood of the pole; the far end of the bulb, which had been glowing for hours from the impact of electrons, being free from silver deposit. Here, then, are two simultaneous actions. Electrons, or radiant matter shot from the negative pole, caused the glass against which they struck to glow with phosphorescent light. Simultaneously, the heavy positive ions of silver, freed from negative electrons, and under the influence of the electrical stress, likewise flew off and were deposited in the metallic state near the pole. The ions of metal thus deposited in all cases showed positive electrification.†

In the years 1893–1895 a sudden impulse was given to electric vacuum work by the publication in German of the remarkable results obtained by Lenard and Röntgen, who showed that the phenomena inside the vacuum tube were surpassed in interest by what took place outside. It is not too much to say that from this date what had been a scientific conjecture became a sober reality.

* In describing the experiment, one of fundamental importance, modern terms are employed.

† *Proc. Roy. Soc.*, Vol. LXIX., p. 421.

Faraday, in 1862, long and ardently sought for a visible relation between magnetism and light which in 1845 he had foreshadowed. But his instrumental means were too feeble, and it was not till 1896 that Zeeman showed a spectrum line could be acted on by a magneic field. A spectrum line is caused by motion of the electron. A magnetic field resolves this motion into other component motions, some slower, others quicker, and thus causes a single line to split into others of greater and less refrangibility than the parent line.

One important advance in theoretic knowledge has been obtained by Dewar, the successor of Faraday in the classic laboratories of the Royal Institution. Soon after Röntgen's discovery Dewar found that the relative opacity to the Röntgen rays was in proportion to the atomic weights of bodies, and he was the first to apply this principle to settling a debated point in connection with argon. Argon is relatively more opaque to the Röntgen rays than either oxygen, nitrogen or sodium, and from this Dewar inferred that the atomic weight of argon was twice its density relative to hydrogen. In the light of to-day's researches on the constitution of atoms, it is impossible to overestimate the importance of this discovery.

In 1896 Becquerel, pursuing the masterly work on phosphorescence inaugurated by his illustrious father, showed that the salts of uranium constantly emit emanations which have the power of penetrating opaque substances and of affecting a photographic plate in total darkness, and of discharging an electrometer. In some respects these emanations, known as Becquerel rays, behave like rays of light, but they also resemble Röntgen rays. Their real character has only recently been ascertained, and even now there is much that is obscure and provisional in the explanation of their constitution and action.

Following closely upon Becquerel's work came the brilliant researches of M. and Mme. Curie, on the radio-activity of bodies accompanying uranium.

Hitherto have been recounting isolated instances of scientific speculation with apparently little relation to one another. The existence of matter in an ultra-gaseous state; material particles smaller than atoms; the existence of electrical atoms or electrons; the constitution of Röntgen rays and their passage through opaque bodies; the emanations from uranium; the dissociation of the elements—all these isolated hypotheses are now focused and welded into one harmonious theory by the discovery of radium.

> "Often do the spirits
> Of great events stride on before the events,
> And in to-day already walks to-morrow."

No new discovery is ever made without its influence ramifying in all directions and explaining much that before had been mystifying. Certainly no discovery of modern times has had such wide-embracing consequences, and thrown such a flood of light on broad regions of hitherto inexplicable phenomena, as this discovery of M. and Mme. Curie and M. Bémont, who patiently and laboriously plodded along a road bristling with difficulties almost insuperable to others who, like myself, have toiled in similar labyrinths of research. The crowning point of these labors is radium.

Let me briefly recount some of the properties of radium, and show how it reduces speculations and dreams, apparently impossible of proof, to a concrete form.

Radium is a metal of the calcium, strontium and barium group. Its atomic weight according to C. Runge and J. Precht is probably about 258. In this case it occupies the third place below barium in my lemniscate spiral scheme of the elements,* two unoccupied gaps intervening.

The spectrum of radium has several well-defined lines; these I have photographed and have also measured their wave-lengths. Two especially are strong and characteristic. One at wave-length 3,649.71 and the other at wave-length 3,814.58. These lines enable radium to be detected spectroscopically.

The emanations cause soda-glass to assume a violet color, and they produce many chemical changes. Their physiological action is strong, a few milligrams brought near the skin in a few hours producing a wound difficult to heal.

The most striking property of radium is its power to pour out torrents of emanations bearing a certain resemblance to Röntgen rays, but differing in important points.

The emanations from radium are of three kinds. One set is the same as the cathode stream, now identified with free electrons—atoms of electricity projected into space apart from gross matter—identical with 'matter in the fourth or ultragaseous state,' Kelvin's 'satellites,' Thomson's 'corpuscles' or 'particles'; Lodge's 'disembodied ionic charges, retaining individuality and identity.' These electrons are neither ether-waves nor a form of energy, but substances possessing inertia (probably electric). Liberated electrons are exceedingly penetrating. They will discharge an electroscope when the radium is ten feet or more away, and will affect a photographic plate through five or six millimeters of lead and several inches of wood or aluminium. They are not readily filtered out by cotton-wool; they do not behave as a gas, *i. e.*, they have not properties dependent on intercollisions, mean free path, etc.; they act more like a fog or mist, are mobile and carried about by a current of air to which they give temporary conducting powers, clinging to positively electrified bodies and thereby losing mobility, and diffusing on the walls of the containing vessel if left quiet.

* *Proc. Roy Soc.*, Vol. LXIII., p. 408.

Electrons are deviable in a magnetic field. They are shot from radium with a velocity of about one tenth that of light, but are gradually obstructed by collisions with air atoms, so that some become much slowed, and then are what I formerly called loose and erratic particles, which diffuse about in the air, and give it temporary conducting powers. These can turn corners, can be concentrated by mica cones into a bundle and then produce phosphorescence.

Another set of emanations from radium are not affected by an ordinarily powerful magnetic field, and are incapable even of passing through thin material obstructions. These emanations have about one thousand times the energy of those radiated by the deflectable particles. They render air a conductor and act strongly on a photographic plate. Their mass is enormous in comparison with that of the electrons, and their velocity is probably as great when they leave the radium, but, in consequence of their greater mass, they are less deflected by the magnet, are easily obstructed by obstacles, and are sooner brought to rest by collisions with air atoms. The Hon. R. B. Strutt* was the first to affirm that these non-deflectable rays are the positive ions moving in a stream from the radioactive body.

Rutherford has shown that these emanations are slightly affected in a very powerful magnetic field, but in an opposite direction to the negative electrons. They are therefore proved to be positively charged bodies moving with great velocity. For

* *Phil. Trans. R. S.*, A, 1901, Vol. CXCVI., p. 525.

the first time Rutherford has measured their speed and mass, and he shows they are ions of matter moving with a speed of the order of that of light.

There is also a third kind of emanation produced by radium. Besides the highly penetrating rays deflected by a magnet, there are very penetrating rays not at all affected by magnetism. These accompany the previous emanations, and are Röntgen rays—ether vibrations—produced as secondary phenomena by the sudden arrest of velocity of the electrons by solid matter, producing a series of Stokesian 'pulses' or explosive ether waves shot into space.

Many lines of argument and research tending towards the same point give trustworthy data by which to calculate the masses and velocities of these different particles. I must deal with big figures, but big and little are relative, and are only of importance in relation to the limitations of our senses. I will take as the standard the atom of hydrogen gas—the smallest material body hitherto recognized. The mass of an electron is 1/700th of an atom of hydrogen, or 3×10^{-26} grm., according to J. J. Thomson, and its velocity is 2×10^{9} centimeters per second, or two thirds that of light The kinetic energy per milligram is 10^{17} ergs, about three and a half million foot-tons. Becquerel has calculated that one square centimeter of radio-active surface would radiate into space one gram of matter in one billion years.

The positively electrified masses or ions are enormously great in comparison with the size of the electron. Sir Oliver Lodge illustrates it thus: If we imagine an ordinary sized church to be an atom of hydrogen, the electrons constituting it will be represented by about 700 grains of sand each the size of an ordinary full-stop (350 positive and 350 negative) dashing in all directions inside, or, according to Lord Kelvin, rotating with inconceivable velocity. Put in another way; the sun's diameter is about one and a half million kilometers, and that of the smallest planetoid about 24 kilometers. If an atom of hydrogen be magnified to the size of the sun, an electron will be about two-thirds the diameter of the planetoid.

The extreme minuteness and sparseness of the electrons in the atom account for their penetration. While the more massive ions are stopped by intercollisions in passing among atoms, so that they are almost completely arrested by the thinnest sheet of matter, electrons will pass almost unobstructed through ordinary opaque bodies.

The action of these emanations on phosphorescent screens is different. The electrons strongly affect a screen of barium platinocyanide, but only slightly one of Sidot's zinc sulphide. On the other hand, the heavy, massive, non-deflectable positive ions affect the zinc sulphide screen strongly, and the barium platinocyanide screen in a much less degree.

Both Röntgen rays and electrons act on a photographic plate and produce images of metal and other substances enclosed in wood and leather, and throw shadows of bodies on a barium platinocyanide screen. Electrons are much less penetrating than Röntgen rays, and will not, for instance, show easily the bones of the hand. A photograph of a closed case of instruments is taken by radium emanations in three days, and by Röntgen rays in three minutes. The resemblance between the two pictures is slight, and the differences great.

The power with which radium emanations are endowed of discharging electrified bodies is due to the ionization of the gas through which they pass. This can be effected in many other ways; thus, ionization is communicated to gases faintly by the splashing of water, by flames and red-hot bodies, by ultra-violet light falling on negatively electrified metals, and strongly by the passage of Röntgen rays.

According to Sir Oliver Lodge's electronic theory of matter, a chemical atom or ion has a few extra negative electrons in addition to the ordinary neutral atom, and if these negative electrons are removed it thereby becomes positively charged. The free electron portion of the atom is small in comparison with the main bulk, in the proportion in hydrogen of about 1 to 700. The negative charge consists of superadded or unbalanced electrons—one, two, three, etc., according to the chemical valency of the body—whereas the main bulk of the atom consists of paired groups, equal positive and negative. As soon as the excess electrons are removed, the rest of the atom, or ion, acts as a massive positively charged body, hanging tightly together. In a high vacuum the induction spark tears the components of a rarefied gas apart; the positively charged ions, having great comparative density are soon slowed down by collisions, while the electrons are driven from the negative pole with an enormous velocity depending on the initial electromotive force and the pressure of gas inside the tube, but approaching, at the highest exhaustions, half that of light.

After leaving the negative pole the electrons meet with a certain resistance, in a slight degree by physical collisions, but principally by reunion with the positive ions.

Since the discovery of radium and the identification of one set of its emanations with the cathode stream or radiant matter of the vacuum tube, speculation and experiment have gone hand in hand, and the two-fluid theory of electricity is gradually replaced by the original one-fluid theory of Franklin. On the two-fluid theory, the electrons constitute free negative electricity, and the rest of the chemical atom is charged positively, although a free positive electron is not known. It seems to me simpler to use the original one-fluid theory of Franklin, and to say that the electron is the atom or unit of electricity. Fleming uses the word 'co-electrons' to express the heavy positive ion after separation from the negative electron: 'We can no more,' he says, 'have anything which can be called electricity apart from corpuscles than we can have momentum apart from moving matter.' A so-called negatively charged chemical atom is one having a surplus of electrons, the number depending on the valency, whilst a positive ion is one having a deficiency of electrons. Differences of electrical charge may thus be likened to debits and credits in one's banking account, the electrons acting as current coin of the realm. On this view only the electron exists; it is the atom of electricity, and the words positive and negative, signifying excess and defect of electrons, are only used for convenience of old-fashioned nomenclature.

The electron theory fits and luminously explains Ampère's idea that magnetism is due to a rotating current of electricity round each atom of iron; and following these definite views of the existence of free electrons, has arisen the electronic theory of matter. It is recognized that electrons have the one property which has been regarded as inseparable from matter—nay, almost impossible to separate from our conception of matter—I mean inertia. Now, in that remarkable paper of J. J. Thomson's published in 1881, he developed the idea of electric inertia (self-induction) as a reality due to a moving charge. The electron therefore appears only as apparent mass by reason of its electrodynamic properties, and if we consider all forms of matter to be merely congeries of electrons, the inertia of matter would be explained without any material basis. On this view the electron would be the 'protyle' of 1886, whose different groupings cause the genesis of the elements.

There is one more property of the emanations of radium to bring before your notice. I have shown that the electrons produce phosphorescence of a sensitive screen of barium platinocyanide, and the positive ions of radium produce phosphorescence of a screen of zinc blende.

If a few minute grains of radium salt fall on the zinc sulphide screen the surface is immediately dotted with brilliant specks of green light. In a dark room, under a microscope with a two-third-inch objective, each luminous spot shows a dull center surrounded by a diffused luminous halo. Outside the halo the dark surface of the screen scintillates with sparks of light. No two flashes succeed on the same spot, but are scattered over the surface, coming and going instantaneously, no movement of translation being seen.

If a solid piece of a radium salt is brought near the screen, and the surface examined with a pocket lens magnifying about 20 diameters, scintillating spots are sparsely scattered over the surface. Bringing the radium nearer the screen the scintillations become more numerous and brighter, until when close together the flashes follow so quickly that the surface looks like a turbulent luminous sea. When the scintillating points are few there is no visible residual phosphorescence, and the successive sparks appear 'atoms of intensest light,' like stars on a black sky. What to the naked eye seems like a uniform 'milky way,' under the lens becomes a multitude of stellar points, flashing over the whole surface.

'Polonium' basic nitrate, actinium and radio-active platinum produce a similar effect on the screen, but the scintillations are fewer. In a vacuum the scintillations are as bright as in air, and being due to inter-atomic motion they are not affected by extremes of low temperature: in liquid hydrogen they are as brilliant as at the ordinary temperature.

A convenient way to show these scintillations is to fit the blende screen at the end of a brass tube with a speck of radium salt in front about a millimeter off, and to have a lens at the other end. I propose to call this little instrument the 'spinthariscope,' from the Greek word *σπινθαρίς*,* a scintillation.

It is difficult to estimate the number of flashes of light per second. With the radium about five centimeters off the screen the flashes are barely detectable, not more than one or two per second. As the distance of the radium diminishes, the flashes become more frequent, until at one or two centimeters, they are too numerous to count, although it is evident this is not of an order of magnitude inconceivably great.

Practically the whole of the luminosity on the blende screen, whether due to radium or 'polonium,' is occasioned by emanations which will not penetrate card. These are the emanations which cause the scintillations, and the reason why they are distinct on the blende and feeble on the platinocyanide screen, is that with the latter the sparks are seen on a luminous

* *'Ενθ' ἐκ νηὸς ὄρουσεν ἄναξ ἑκάεργος 'Απόλλων,*
ἀστέρι εἰδόμενος, μέσῳ ἤματι τοῦ δ' ἀπὸ πολλαί
σπινθαρίδες πωτῶντο, σέλας δ' εἰς οὐρανὸν ἶκεν'.

(Here from the ship leaped the far-darting Apollo, like a star at midday, while from him flitted scintillations of fire, and the brilliancy reached to heaven.) Homer's 'Hymen to Apollo,' lines 440–442.

ground of general phosphorescence which renders the eye less able to see the scintillations.

It is probable that in these phenomena we actually witness the bombardment of the screen by the positive ions hurled off by radium with a velocity of the order of that of light. Each particle is rendered apparent only by the enormous extent of lateral disturbance produced by its impact on the sensitive surface, just as individual drops of rain falling on a still pool are not seen as such, but by reason of the splash they make on impact, and the ripples and waves they produce in ever-widening circles.

Indulging in a 'scientific use of the imagination,' and pushing the hypothesis of the electronic constitution of matter to what I consider its logical limit, we may be, in fact, witnessing a spontaneous dissociation of radium—and we begin to doubt the permanent stability of matter. The chemical atom may be actually suffering a katabolic transformation; but at so slow a rate that supposing a million atoms fly off every second, it would take a century for weight to diminish by one milligram.

It must never be forgotten that theories are only useful so long as they admit of the harmonious correlation of facts into a reasonable system. Directly a fact refuses to be pigeon-holed and will not be explained on theoretic grounds, the theory must go, or it must be revised to admit the new fact. The nineteenth century saw the birth of new views of atoms, electricity and ether. Our views to-day of the constitution of matter may appear satisfactory to us, but how will it be at the close of the twentieth century? Are we not incessantly learning the lesson that our researches have only a provisional value? A hundred years hence shall we acquiesce in the resolution of the material universe into a swarm of rushing electrons?

This fatal quality of atomic dissociation appears to be universal and operates whenever we brush a piece of glass with silk; it works in the sunshine and raindrops, and in the lightnings and flame; it prevails in the waterfall and the stormy sea, and although the whole range of human experience is all too short to afford a parallax whereby the date of the extinction of matter can be calculated, protyle, the 'formless mist,' once again may reign supreme, and the hour hand of eternity will have completed one revolution.

WILLIAM CROOKES.

SCIENTIFIC BOOKS.

Index Animalium, sive index nominum quæ ab A. D. MDCCLVIII, generibus et speciebus animalium imposita sunt. By C. DAVIES SHERBORN. Part I., January, 1758, to December, 1800. Cambridge (England), University Press. (New York, Macmillan Co.) 1902. 8vo. Pp. lix + 1195.

All zoologists have been aware of the stupendous undertaking upon which Mr. Sherborn has been at work for the last twelve years, except for an interval during which his health was so impaired as to necessitate a temporary interruption.

The aim of the undertaking was 'to provide zoologists with a list of all the generic and specific names which have been applied by authors to animals since January 1, 1758,' together with an exact date for each page cited, and a reference 'sufficiently exact to be intelligible alike to the specialist and to the layman.' Special groups of animals have been so treated before, but this is the first work planned to include the entire animal kingdom in its scope.

Work was begun in July, 1890; in 1892 the British Association extended its support, and two years later appointed a committee to watch and advise the undertaking. Financial support has also been extended by the Royal Society and the Zoological Society of London.