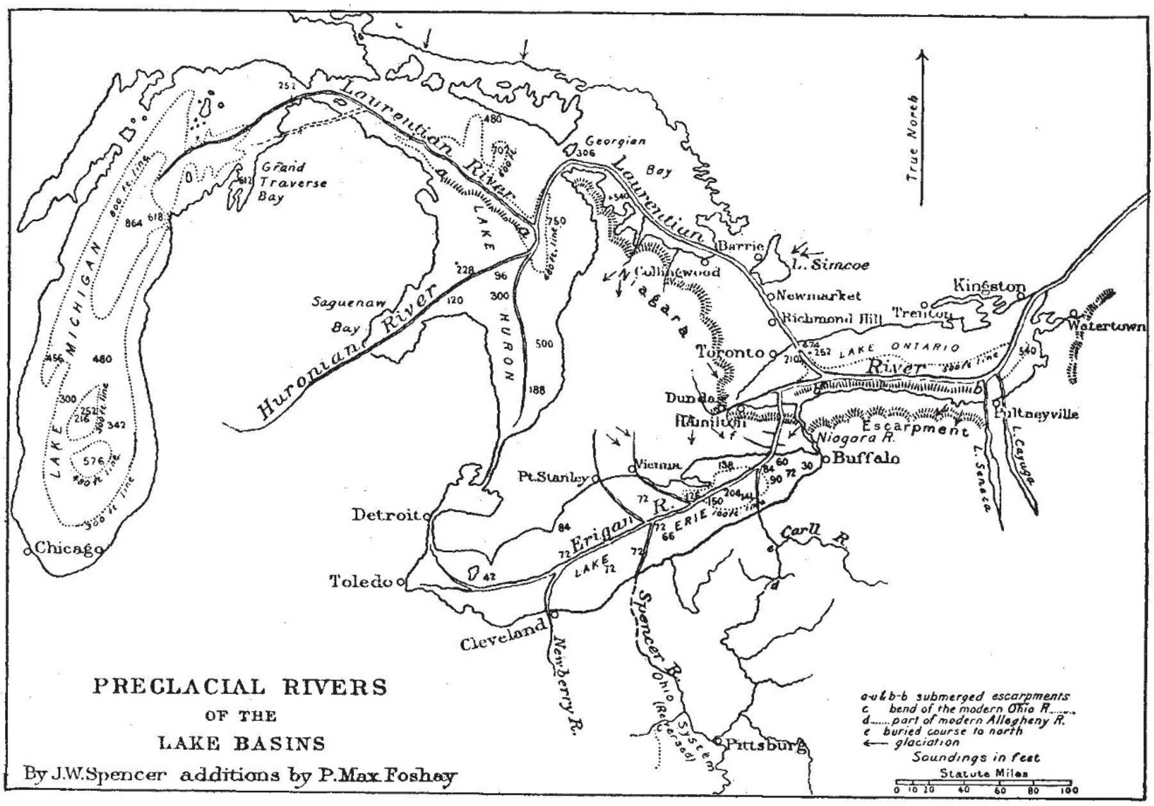
by the electric power companies has already reduced their beauty, and if the existing projects are carried into effect the American Fall will be reduced to a few threads of water and the Canadian Fall rendered comparatively insignificant. The second danger is the possible tilting of the area of the Great Lakes, which would, at the rate of movement estimated by Dr. G. K. Gilbert, bring Niagara to a close in about 3500 or 5000 years. This theory is of great interest, as it has been generally advanced as the best established case of a still progressing uplift of a large area of the earth's crust. Dr. Spencer, however, rejects this conclusion, and though he lays great stress on recent earth-movements in the region to the north-east of the Great Lakes, he claims that the lake region itself has been quite stable, and that no earth-movements are now taking place there. The facts advanced to prove the supposed uplift he holds can be explained by seasonal and meteorological changes.



Map of the Pre-Glacial Valleys of the Great Lake Region

The Geological Survey of Canada is to be congratulated on this interesting, well illustrated, and important memoir. Its value renders all the more regrettable the inclusion of a series of personal charges against one of the most respected of American geologists, which are quite out of place in an official publication.

J. W. GREGORY.

THE NATURE AND CHARGE OF THE α PARTICLES FROM RADIO-ACTIVE SUBSTANCES.

THE development of our knowledge of radio-activity has emphasised the primary importance of the α particles, which are projected in great numbers from most of the active substances. As Rutherford showed in 1903, the α particles are veritable atoms of matter which are ejected from radio-active matter at a speed of about 10,000 miles per second. The great number of α particles which are projected from radium is well illustrated by the multitude of scintillations observed when the α particles from a trace of radium fall on a screen of zinc sulphide. We shall see later that 136 million α particles are expelled every second from one milligram of radium in radio-active equilibrium. From the point of view of modern theory, the appearance of an α particle is the sign of a violent atomic explosion in which a fragment of the atom—an α particle—is ejected at a high speed. In the majority of the known active substances, the expulsion of an α particle accompanies the transformation of one substance into another, and the decrease of atomic mass consequent upon the loss of an α particle at once offers a reasonable explanation of the appearance of an entirely new kind of matter in place of the old.

Space does not allow us here to discuss the very interesting facts that have been brought to light by the work of Bragg and Kleeman and others in regard to the character of the absorption of the α particle by matter. It suffices to say that it has been found that the α particles from one kind of active matter are all projected initially at an identical speed, but that this initial velocity varies within comparatively narrow limits for different kinds of matter. The α particle, in consequence of its great energy of motion, plunges through the molecules of matter in its path, leaving in its train a large number of dissociated or ionised molecules. Some important questions at once arose when it was found that the α particle was an atom of matter of mass comparable with the hydrogen atom, viz., Are the α particles expelled from different kinds of matter identical in constitution, and are the α particles atoms of a known element or some new kind of matter?

These problems were attacked by determining the velocity and the value of E/M—the ratio of the charge carried by an α particle to its mass—of α particles expelled from different kinds of matter. These quantities can be determined by measuring the deflection of a pencil of α rays when passing through strong magnetic and electric fields. Experiments of this kind, which are difficult on account of the small deflection of the α rays under normal experimental conditions, have been made by Rutherford, Des Coudres, Mackenzie, and Huff. The former determined the velocity and value of E/M for each of a number of products of radium and actinium, while Rutherford and Hahn made similar measurements for some of the products of thorium. The results were of great interest, for while it was found that the initial velocity of projection of the α particles from different kinds of matter varied from about 14,000 to 10,000 miles per second, the value of E/M was the same for all. This shows that the α particle, whether expelled from radium, thorium, or actinium, is identical in mass and constitution, and that all the radio-active substances which emit α particles have a common product of disintegration. As the result of a number of experiments, Rutherford found that the value E/M for the α particle was 5070 in electromagnetic units. Now, from experiments on the electrolysis of water, it is known that the corresponding value of e/m for the hydrogen atom is 9600, or nearly twice as large. The charge e carried by the H atom is believed to be the fundamental unit charge of electricity, so that the charge carried by any body must be an integral multiple of e. If we suppose the charge carried by an α particle is equal to the charge carried by an hydrogen atom, the mass of the α particle is, in round numbers, twice that of the hydrogen atom, *i.e.* is equal to the molecule of hydrogen. If, however, we suppose that $E=2e$, *i.e.* the α particle carries two unit charges, the mass of the α particle is equal to about four. Now, it is known that the atomic mass of helium is 3·96 in terms of hydrogen, so that on this supposition the α particle would appear to be an atom of helium carrying two unit charges. We must now consider some indirect evidence bearing on the question. As the result of the experiments of Ramsay and Soddy and others, it is now well substantiated that helium is produced from radium. Debierne has shown that helium is produced also from actinium. Unless the helium is the result of the accumulated α particles, it is difficult to account for the production of the helium observed. In addition, as we have shown, the α particle is the only known common product of the disintegration of radium and actinium, which both give rise to helium. For these and other reasons, Rutherford suggested in 1905 that it was very probable that the α particle was an atom of helium carrying two unit charges. It has been found exceedingly difficult experimentally either to prove or disprove the correctness of this hypothesis, although the settlement of this question has been for the last few years the most important problem in radioactivity, for, as will be seen, the proof that the α particle is an atom of helium carries numerous consequences of the first importance in its train.

We shall now describe some novel experiments by Rutherford and H. Geiger, which have not only thrown further light on this question, but have led to important conclusions in several directions. An account of this work is contained in two papers published in the Proceedings of the Royal Society, entitled "An Electrical Method of Counting the α Particles from Radio-active Matter," and "The Charge and Nature of the α Particle" (A. vol. lxxxi., 141–174, 1908).

In the first paper an account is given of a method for the detection of a single α particle and for counting the number of α particles emitted from one gram of radium.

The current due to the ionisation of the gas produced by a single α particle is too small to detect except by exceedingly refined methods. To overcome this difficulty, recourse was had to a method of automatic magnification of this current, based on the principle of generation of ions by collision—a subject which has been investigated in detail by Townsend and others. Space does not allow us to enter into a description of the methods employed for this purpose or of the various experimental difficulties that arose during the investigation. The general method employed was to allow the α particles to be fired through a small opening into a detecting vessel containing gas at low pressure exposed to an electric field not far from the sparking value. The entrance of an α particle into the detecting vessel was marked by a sudden ballistic throw of the electrometer needle. By adjustment of the electric field, it was found possible to obtain so large a magnification that the entrance of a single α particle was marked by a large excursion of the electrometer needle.

In this way the expulsion of α particles was detected from uranium, thorium, radium, and actinium. In order to count accurately the number of α particles expelled from one gram of radium, not radium itself, but its product radium C was used as a source of radiation. A surface was coated with a thin film of radium C by its exposure for some hours in the presence of the radium emanation. The use of radium C as a source of rays had several advantages, especially as regards the ease and certainty of measurement of the amount of active matter present by means of the γ rays. The number of α particles passing through an opening of known area at a known distance from the active source was counted for a definite interval by noting the excursions of the electrometer needle. From this the total number of α particles expelled per second from the source was deduced. In this way it was found that $3{\cdot}4\times10^{10}$ α particles were expelled per second from the radium C present in one gram of radium in equilibrium. It is known from other data that radium itself and each of its products, viz. the emanation, radium A and radium C, expel the same number of α particles per second when in equilibrium. Consequently in one gram of radium in equilibrium $3{\cdot}4\times10^{10}$ α particles are expelled from each of the products per second, and the total number expelled is $1{\cdot}36\times10^{11}$ per second. On the most probable assumption, that one atom of radium in breaking up emits one α particle, $3{\cdot}4\times10^{10}$ atoms of radium break up per second per gram.

It was a matter of interest to compare the number of scintillations observed on a properly prepared screen of zinc sulphide with the number of α particles striking it. Within the limit of experimental error, it was found that the number of scintillations was equal to the number of impinging α particles counted by the electric method. Consequently each α particle on striking the screen produces a scintillation. It is thus obvious that, using proper screens, the scintillation method as well as the electric method may be employed to count the number of α particles emitted by a radio-active substance.

Apart from the importance of these results for radio-active data, the experiments are of themselves noteworthy, for it is the first time that it has been found possible to detect a single atom of matter.

This, as we have seen, can be done in two ways, one electrical and the other optical. The possibility of detection of a single atom of matter is in this case, of course, due to the great energy of motion of the α particle.

In the second paper, an account is given of experiments to measure the charge carried by the α particles. Since the number of α particles is known from the counting experiments, the charge on each α particle can be determined by measuring the charge carried by the α particles expelled from a known quantity of radium. As in the counting experiments, radium C was used as a source of rays. It was found that each α particle carried a positive charge of $9{\cdot}3 \times 10^{-10}$ electrostatic units. Now the charge carried by an ion in gases has been determined by several observers, using the well-known method of making each ion the nucleus of a visible drop of water by a sudden expansion. J. J. Thomson obtained a value $3{\cdot}4 \times 10^{-10}$, H. A. Wilson $3{\cdot}1 \times 10^{-10}$, and Millikan and Begeman $4{\cdot}06 \times 10^{-10}$.

The mean of these three determinations of e is $3{\cdot}5 \times 10^{-10}$. The charge E on an α particle on this data thus lies between $2e$ and $3e$.

Some calculations of the value of E and e are then made from radio-active data based on simple and very probable assumptions. Taking the half-period of transformation of radium as 2000 years—the value found by direct measurement by Boltwood—it is shown, on the assumption that each atom of radium in breaking up emits one α particle, that the charge e carried by a hydrogen atom comes out to be $4{\cdot}1 \times 10^{-10}$. Similarly, supposing that the heating effect of radium is a measure of the kinetic energy of the α particles, the charge carried by an α particle comes out at $9{\cdot}1 \times 10^{-10}$—a value close to that found experimentally. A discussion is then given of the methods employed in the previous determination of e, and it is shown that in consequence of certain sources of error which are very difficult to eliminate, the values previously obtained tend to be too small. It is concluded that the unit charge e is not very different from E/2 or $4{\cdot}65 \times 10^{-10}$, and that an α particle carries twice the unit charge. From the previous discussion of the interpretation of the value of E/M for the α particle, it follows that an α particle must be an atom of helium carrying a double charge, or, in other words, that an α particle when its charge is neutralised is a helium atom.

It seems at first sight contradictory that an atom of a monatomic gas like helium can carry two unit charges. It must be borne in mind that in this case the α particle plunges at a great speed through the molecules of matter, and must itself be ionised by collision. If two electrons can be removed by this process, the double positive charge is at once explained.

We thus see that by a direct method we have been enabled to count the number of α particles and to determine the charge caused by each, and from other evidence to deduce that the unit charge e is half the charge carried by the α particle.

With the aid of this data we can at once deduce the magnitudes of some important atomic quantities. The value of e/m for the hydrogen atom is $2{\cdot}88 \times 10^{14}$ electrostatic units. Substituting the value of $e = 4{\cdot}65 \times 10^{-10}$, it follows that the mass of a hydrogen atom is $1{\cdot}61 \times 10^{-24}$ gram. From this it follows that there are $6{\cdot}2 \times 10^{23}$ atoms in one gram of hydrogen, and that there are $2{\cdot}72 \times 10^{19}$ molecules in a cubic centimetre of any gas at standard pressure and temperature.

From the data already given we can predetermine the magnitude of some important radio-active quantities. Let us first consider the rate of production of helium by radium. One gram of radium in equilibrium contains four α-ray products, each of which expels $3{\cdot}4 \times 10^{10}$ α particles, *i.e.* atoms of helium, per second. Consequently, since there are $2{\cdot}72 \times 10^{19}$ atoms of helium in a cubic centimetre, the volume of helium produced per second is $\frac{4 \times 3{\cdot}4 \times 10^{10}}{2{\cdot}72 \times 10^{19}}$, or $5{\cdot}0 \times 10^{-6}$ c.mm. per second. This corresponds to a production of helium of 0·43 c.mm. per day, or 158 c.mm. per year.

In a similar way, the maximum volume of the emanation in one gram of radium can be calculated. Since one atom of radium in breaking up emits one α particle and gives rise to one atom of emanation, the volume of emanation produced per second is one-quarter the volume of helium, or $1{\cdot}25 \times 10^{-6}$ c.mm. per second. Since the average life of the emanation is 468,000 seconds, the maximum volume of the emanation comes out to be 0·585 c.mm. In a recent paper Rutherford (*Phil. Mag.*, August) has measured the volume of the emanation and obtained a value not very different from the calculated volume. In a similar way, it is not difficult to calculate the period of transformation of radium and the heating effect of radium. The former comes out at 1750 years, which is somewhat shorter than the value 2000 years found experimentally by Boltwood. As Boltwood points out, however, the probable experimental errors are such as to tend to give too high a value for the period. The latter is deduced on the hypothesis that the heating effect is a measure of the kinetic energy of the expelled α particles. The heating effect is calculated to be about 113 gram calories per gram per hour, while the observed heating effect of the sample of radium from which the standard preparation was taken was found to be 110 gram calories per hour. For convenience, the data obtained in this paper are collected below:—

Charge carried by a hydrogen atom	$= 4{\cdot}65 \times 10^{-10}$ electrostatic units.
Charge carried by α particle	$= 9{\cdot}3 \times 10^{-10}$ electrostatic units.
Mass of H atom	$= 1{\cdot}61 \times 10^{-24}$ gram.
Number of atoms per gram of H	$= 6{\cdot}2 \times 10^{23}$
Number of molecules per c.c. of any gas at standard pressure and temperature ...	$= 2{\cdot}72 \times 10^{19}$
Number of α particles expelled per sec. per gram of radium itself	$= 3{\cdot}4 \times 10^{10}$
Number of atoms breaking up per sec. per gram of radium	$= 3{\cdot}4 \times 10^{10}$
Calculated volume of emanation per gram of radium	$= 0{\cdot}585$ c.mm.
Production of helium per gram of radium per year	$= 158$ c.mm.
Calculated heating effect of radium per gram	$= 113$ gr. cal. per hour.
Calculated period of radium...	$= 1750$ years.

We have already seen that there is a substantial agreement between the calculated values of the heating effect, the life of radium and the volume of the emanation, and the experimentally determined values. A still further test would lie in a comparison of the calculated and observed rates of production of helium by radium. Data on this subject will probably soon be forthcoming.[1]

Some very important consequences follow from the proof that the α particle is a helium atom. It must be concluded that the atoms of the known radio-active elements are in part at least constituted of helium atoms which are liberated at definite stages during

[1] (Footnote, added September 12, 1908.) In a paper just to hand (Proc. Roy. Soc., A., vol. lxxxi., p. 280) Sir James Dewar has shown experimentally that 0·37 c.mm. of helium is produced per gram of radium per day. This is in excellent agreement with the calculated rate, 0·43 c.mm. per day.

the disintegration. It will be seen that in many cases the atomic weights of the various products can be deduced. In the succession of products produced by the disintegration of the uranium-radium series, there occur several rayless products and β-ray products. Assuming, as is not improbable, that the atomic products undergo an internal rearrangement without the expulsion of a mass comparable with the hydrogen atom, we can calculate the atomic weights of the successive products, taking the atomic weight of helium as 4. From the known range of the α particles from uranium and the ionisation it produces compared with the radium associated with it, there is no doubt that uranium expels two α particles to one from radium itself. Whether this is a peculiarity of uranium itself or due to an unseparated product in uranium is not settled.

Taking the atomic weight of uranium as 238·5, the atomic weights of the different products are as follows:—Uranium X 230·5, ionium 230·5, radium 226·5, emanation 222·5, radium A 218·5, radium B 218·5, radium C 214·5, radium D, E, and F (radio-lead) 210·5, radium A (polonium) 210·5. It will be seen that the calculated value of the atomic weight of radium is in good agreement with the most recent experimental values. The end product of radium after the transformation of polonium has an atomic weight of 206·5—a value close to that of lead (206·9). Boltwood long ago suggested, from examination of the amount of lead in old radio-active minerals, that lead was the probable final product of the disintegration of the uranium-radium series.

We cannot at the moment apply the same method of calculation to thorium products, for Bronson (*Phil. Mag.*, August, 1908) has recently brought strong evidence that the disintegration of the atoms of some of the products is accompanied by the expulsion of more than one α particle.

In conclusion, it may be of interest to note that the experimental results recorded in this article lead to an experimental proof—if proof be needed—of the correctness of the atomic hypothesis with reference to the discrete structure of matter. The number of α particles expelled from radium can be directly counted, and the corresponding volume of helium determined. In this way it is possible to determine directly the number of atoms in a cubic centimetre of helium quite independently of any measurements of the charge carried by the α particles.

E. RUTHERFORD.

NOTES.

THE following is a list of the fellows recommended by the president and council of the Royal Society for election into the council for the year 1908–9:—*President*, Sir Archibald Geikie, K.C.B.; *treasurer*, Dr. Alfred Bray Kempe; *secretaries*, Prof. Joseph Larmor, Prof. John Rose Bradford; *foreign secretary*, Sir William Crookes; *other members of council*, Sir George Howard Darwin, K.C.B., Prof. J. C. Ewart, Sir David Gill, K.C.B., Dr. J. S. Haldane, Mr. C. T. Heycock, Prof. Horace Lamb, Prof. H. M. Macdonald, Dr. F. W. Mott, Hon. C. A. Parsons, C.B., Prof. W. H. Perkin, Prof. E. B. Poulton, Lieut.-Colonel D. Prain, Sir Arthur W. Rücker, Right Hon. Sir James Stirling, Prof. F. T. Trouton, Mr. W. Whitaker.

THE Royal Society's medals have this year been adjudicated by the president and council as follows:—The Copley medal to Dr. Alfred Russel Wallace, in recognition of the great value of his numerous contributions to natural history, and of the part he took in working out the theory of the origin of species by natural selection; the Rumford medal to Prof. H. A. Lorentz, for his investigations in optical and electrical science; a Royal medal to Prof. John Milne, for his preeminent services in the modern development of seismological science; a Royal medal to Dr. Henry Head, for his researches on the relations between the visceral and somatic nerves and on the functions of the afferent nerves; the Davy medal to Prof. W. A. Tilden, for his discoveries in chemistry, especially on the terpenes and on atomic heats; the Darwin medal to Prof. August Weismann, for his eminent services in support of the doctrine of evolution by means of natural selection; the Hughes medal to Prof. Eugen Goldstein, for his discoveries on the nature of electric discharge in rarefied gases.

M. PHILIPPE VAN TIEGHEM has been elected the permanent secretary of the Paris Academy of Sciences in succession to the late M. Becquerel.

THE International Congress of Geology will be held at Stockholm in 1910, when it is expected that Baron Gérard de Geer will, on his return from the Arctic regions, read a paper on polar geology.

A DEPUTATION from the Incorporated Society for the Destruction of Vermin waited upon Lord Carrington at the offices of the Board of Agriculture on October 29 to request the Government to appoint a commission to inquire into the damage to crops done by rats.

AN agreement has been signed by which England and Germany undertake to cooperate in combating the sleeping sickness in their East African possessions. The cooperation will take the form chiefly of exchanging reports of cases, and in arranging for the destruction of wild animals which act as "reservoirs," or provide nourishment, for the trypanosomes of sleeping sickness.

A COURSE of twelve lectures—the Swiney lectures on geology—on the geological history of the American fauna will be delivered by Dr. R. F. Scharff in the lecture theatre of the Victoria and Albert Museum, South Kensington, on Mondays, Wednesdays, and Fridays at 5 p.m. The first lecture was given on Monday last, November 2. Admission to the course is free.

WE learn through the *British Medical Journal* that Prof. Ehlers, of Copenhagen, well known as an authority on leprosy, is now in Paris with the view of organising a scientific expedition to the Danish West Indies, which comprise the islands of St. Thomas, St. John, and Santa Cruz. The object of the expedition is said to be to endeavour to determine the part played by blood-sucking insects, especially fleas and bugs, in the dissemination of leprosy.

THE Bisset Hawkins gold medal of the Royal College of Physicians has been awarded to Sir Shirley Murphy, medical officer of health of the County of London, for his distinguished services in the cause of public health. The FitzPatrick lectures of the college will be delivered on November 5 and 10 by Dr. Leonard Guthrie, on "The History of Neurology," and the Horace Dobell lecture by Mr. Leonard Dudgeon, on November 12, on "The Latent Persistence and the Reactivation of Pathogenic Bacteria in the Body."

ON October 30 Mr. Farman flew, with a machine heavier than air, seventeen miles across country in twenty minutes, from Châlons to a point just outside Rheims. The height of the course of flight was about 150 feet. On October 31 M. Blériot made flights across country from his station near Chartres, the longest being one of