SCIENCE

VOL. 92 FRIDAY, SEPTEMBER 6, 1940 No. 2384

Radioactivity: SIR JOSEPH THOMSON ... 207
The Origin of the Earth's Land Formations: DR. C. D. PERRINE ... 210
Scientific Events:
The Biological Research Institute of the Zoological Society of San Diego; The Great Smoky Mountains National Park; The Marine Biological Laboratory at Woods Hole; The Detroit Meeting of the American Chemical Society. Recent Deaths ... 212
Scientific Notes and News ... 214
Discussion:
The First Thousand Mathematical Works Printed in America: PROFESSOR G. A. MILLER. *Practical Suggestions for Reducing the Labor of Indexing a Text-book:* DR. LEON HUGH WARREN. *The Incidence of Hydrogen Sulfide at Kilauea Solfatara Preceding the 1940 Mauna Loa Volcanic Activity:* DR. JOHN H. PAYNE and DR. STANLEY S. BALLARD 216
Scientific Books:
A Geological Expedition to the Sunda Islands: PROFESSOR REGINALD A. DALY. *The Invertebrates:* DR. WILLIAM F. DILLER ... 219
Reports:
Summarized Proceedings of the American Association for the Advancement of Science from 1934 to 1940: DR. F. R. MOULTON ... 221
Special Articles:
Morphological and Functional Recovery of the Pancreatic Islands in Diabetic Cats Treated with Insulin: DR. F. D. W. LUKENS and DR. F. C. DOHAN. *The Neuro-Motor Mechanism of the Small Blood Vessels of the Frog:* GEORGE P. FULTON and DR. BRENTON R. LUTZ. *Egg-white Injury in Chicks and Its Relationship to a Deficiency of Vitamin H (Biotin):* ROBERT E. EAKIN, WILLIAM A. MCKINLEY and PROFESSOR ROGER J. WILLIAMS ... 222
Scientific Apparatus and Laboratory Methods:
Molecular Weight by Isothermic Distillation: PROFESSOR JOSEPH B. NIEDERL and ARTHUR M. LEVY. *A Simple Stain for Tissue Cultures:* JANE STANLEY CRAIG ... 225
Science News ... 10

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary in the Smithsonian Institution Building, Washington, D. C.

RADIOACTIVITY[1]

By the late SIR JOSEPH (JOHN) THOMSON, Master of Trinity College, Cambridge

I NOW pass to a very brief consideration of one of the most important and interesting advances ever made in physics, and in which Canada, as the place of the labors of Professors Rutherford and Soddy, has taken a conspicuous part. I mean the discovery and investigation of radioactivity. Radioactivity was brought to light by the Röntgen rays. One of the many remarkable properties of these rays is to excite phosphorescence in certain substances, including the salts of uranium, when they fall upon them. Since Röntgen rays produce phosphorescence, it occurred to Becquerel to try whether phosphorescence would produce Röntgen rays. He took some uranium salts which had been made to phosphoresce by exposure, not to Röntgen rays but to sunlight, tested them, and found that they gave out rays possessing properties similar to Röntgen rays. Further investigation showed, however, that to get these rays it was not necessary to make the uranium phosphoresce, that the salts were just as active if they had been kept in the dark. It thus appeared that the property was due to the metal and not to the phosphorescence, and that uranium and its compounds possessed the power of giving out rays which, like Röntgen rays, affect a photographic plate, make certain minerals phosphoresce, and make gases through which they pass conductors of electricity.

Niepce de Saint-Victor had observed some years before this discovery that paper soaked in a solution of uranium nitrate affected a photographic plate, but the observation excited but little interest. The ground had

[1] Concluding portion of the address of the president of the British Association for the Advancement of Science, given at Winnipeg in 1909. Reprinted from the issue of SCIENCE for August 27, 1909. Sir Joseph Thomson died on August 30.

not then been prepared, by the discovery of the Röntgen rays, for its reception, and it withered and was soon forgotten.

Shortly after Becquerel's discovery of uranium, Schmidt found that thorium possessed similar properties. Then Monsieur and Madame Curie, after a most difficult and laborious investigation, discovered two new substances, radium and polonium, possessing this property to an enormously greater extent than either thorium or uranium, and this was followed by the discovery of actinium by Debierne. Now the researches of Rutherford and others have led to the discovery of so many new radioactive substances that any attempt at christening seems to have been abandoned, and they are denoted, like policemen, by the letters of the alphabet.

Mr. Campbell has recently found that potassium, though far inferior in this respect to any of the substances I have named, emits an appreciable amount of radiation, the amount depending only on the quantity of potassium, and being the same whatever the source from which the potassium is obtained or whatever the elements with which it may be in combination.

The radiation emitted by these substances is of three types known as α, β and γ rays. The α rays have been shown by Rutherford to be positively electrified atoms of helium, moving with speeds which reach up to about one tenth of the velocity of light. The β rays are negatively electrified corpuscles, moving in some cases with very nearly the velocity of light itself, while the γ rays are unelectrified, and are analogous to the Röntgen rays.

The radioactivity of uranium was shown by Crookes to arise from something mixed with the uranium, and which differed sufficiently in properties from the uranium itself to enable it to be separated by chemical analysis. He took some uranium, and by chemical treatment separated it into two portions, one of which was radioactive and the other not.

Next Becquerel found that if these two portions were kept for several months, the part which was not radioactive to begin with regained radioactivity, while the part which was radioactive to begin with had lost its radioactivity. These effects and many others receive a complete explanation by the theory of radioactive change which we owe to Rutherford and Soddy.

According to this theory, the radioactive elements are not permanent, but are gradually breaking up into elements of lower atomic weight; uranium, for example, is slowly breaking up, one of the products being radium, while radium breaks up into a radioactive gas called radium emanation, the emanation into another radioactive substance, and so on, and that the radiations are a kind of swan's song emitted by the atoms when they pass from one form to another; that, for example, it is when a radium atom breaks up and an atom of the emanation appears that the rays which constitute the radioactivity are produced.

Thus, on this view the atoms of the radioactive elements are not immortal, they perish after a life whose average value ranges from thousands of millions of years in the case of uranium to a second or so in the case of the gaseous emanation from actinium.

When the atoms pass from one state to another they give out large stores of energy, thus their descendants do not inherit the whole of their wealth of stored-up energy, the estate becomes less and less wealthy with each generation; we find, in fact, that the politician, when he imposes death duties, is but imitating a process which has been going on for ages in the case of these radioactive substances.

Many points of interest arise when we consider the rate at which the atoms of radioactive substances disappear. Rutherford has shown that whatever be the age of these atoms, the percentage of atoms which disappear in one second is always the same; another way of putting it is that the expectation of life of an atom is independent of its age—that an atom of radium one thousand years old is just as likely to live for another thousand years as one just sprung into existence.

Now this would be the case if the death of the atom were due to something from outside which struck old and young indiscriminately; in a battle, for example, the chance of being shot is the same for old and young; so that we are inclined at first to look to something coming from outside as the cause why an atom of radium, for example, suddenly changes into an atom of the emanation. But here we are met with the difficulty that no changes in the external conditions that we have as yet been able to produce have had any effect on the life of the atom; as far as we know at present the life of a radium atom is the same at the temperature of a furnace as at that of liquid air—it is not altered by surrounding the radium by thick screens of lead or other dense materials to ward off radiation from outside, and what to my mind is especially significant, it is the same when the radium is in the most concentrated form, when its atoms are exposed to the vigorous bombardment from the rays given off by the neighboring atoms, as when it is in the most dilute solution, when the rays are absorbed by the water which separates one atom from another. This last result seems to me to make it somewhat improbable that we shall be able to split up the atoms of the non-radioactive elements by exposing them to the radiation from radium; if this radiation is unable to affect the unstable radioactive atoms, it is somewhat unlikely that it will be able to affect the much more stable non-radioactive elements.

The evidence we have at present is against a disturbance coming from outside breaking up of the radioactive atoms, and we must therefore look to some process of decay in the atom itself; but if this is the case, how are we to reconcile it with the fact that the expectation of life of an atom does not diminish as the atom gets older? We can do this if we suppose that the atoms when they are first produced have not all the same strength of constitution, that some are more robust than others, perhaps because they contain more intrinsic energy to begin with, and will therefore have a longer life. Now if when the atoms are first produced there are some which will live for one year, some for ten, some for a thousand, and so on; and if lives of all durations, from nothing to infinity, are present in such proportions that the number of atoms which will live longer than a certain number of years decrease in a constant proportion for each additional year of life, we can easily prove that the expectation of life of an atom will be the same whatever its age may be. On this view the different atoms of a radioactive substance are not, in all respects, identical.

The energy developed by radioactive substances is exceedingly large, one gram of radium developing nearly as much energy as would be produced by burning a ton of coal. This energy is mainly in the α particles, the positively charged helium atoms which are emitted when the change in the atom takes place; if this energy were produced by electrical forces it would indicate that the helium atom had moved through a potential difference of about two million volts on its way out of the atom of radium. The source of this energy is a problem of the deepest interest; if it arises from the repulsion of similarly electrified systems exerting forces varying inversely as the square of the distance, then to get the requisite amount of energy the systems, if their charges were comparable with the charge on the α particle, could not when they start be further apart than the radius of a corpuscle, 10^{-13} cm. If we suppose that the particles do not acquire this energy at the explosion, but that before they are shot out of the radium atom they move in circles inside this atom with the speed with which they emerge, the forces required to prevent particles moving with this velocity from flying off at a tangent are so great that finite charges of electricity could only produce them at distances comparable with the radius of a corpuscle.

One method by which the requisite amount of energy could be obtained is suggested by the view to which I have already alluded—that in the atom we have electrified systems of very different types, one small, the other large; the radius of one type is comparable with 10^{-13} cm., that of the other is about 100,000 times greater. The electrostatic potential energy in the smaller bodies is enormously greater than that in the larger ones; if one of these small bodies were to explode and expand to the size of the larger ones, we should have a liberation of energy large enough to endow an α particle with the energy it possesses. Is it possible that the positive units of electricity were, to begin with, quite as small as the negative, but while in the course of ages most of these have passed from the smaller stage to the larger, there are some small ones still lingering in radioactive substances, and it is the explosion of these which liberates the energy set free during radioactive transformation?

The properties of radium have consequences of enormous importance to the geologist as well as to the physicist or chemist. In fact, the discovery of these properties has entirely altered the aspect of one of the most interesting geological problems, that of the age of the earth. Before the discovery of radium it was supposed that the supplies of heat furnished by chemical changes going on in the earth were quite insignificant, and that there was nothing to replace the heat which flows from the hot interior of the earth to the colder crust. Now when the earth first solidified it only possessed a certain amount of capital in the form of heat, and if it is continually spending this capital and not gaining any fresh heat it is evident that the process can not have been going on for more than a certain number of years, otherwise the earth would be colder than it is. Lord Kelvin in this way estimated the age of the earth to be less than 100 million years. Though the quantity of radium in the earth is an exceedingly small fraction of the mass of the earth, only amounting, according to the determinations of Professors Strutt and Joly, to about five grams in a cube whose side is 100 miles, yet the amount of heat given out by this small quantity of radium is so great that it is more than enough to replace the heat which flows from the inside to the outside of the earth. This, as Rutherford has pointed out, entirely vitiates the previous method of determining the age of the earth. The fact is that the radium gives out so much heat that we do not quite know what to do with it, for if there was as much radium throughout the interior of the earth as there is in its crust, the temperature of the earth would increase much more rapidly than it does as we descend below the earth's surface. Professor Strutt has shown that if radium behaves in the interior of the earth as it does at the surface, rocks similar to those in the earth's crust can not extend to a depth of more than forty-five miles below the surface.

It is remarkable that Professor Milne from the study of earthquake phenomena had previously come to the conclusion that rocks similar to those at the earth's surface only descend a short distance below the surface; he estimates this distance at about thirty miles, and concludes that at a depth greater than this the earth is fairly homogeneous. Though the discovery of radioactivity has taken away one method of calculating the age of the earth it has supplied another.

The gas helium is given out by radioactive bodies, and since, except in beryls, it is not found in minerals which do not contain radioactive elements, it is probable that all the helium in these minerals has come from these elements. In the case of a mineral containing uranium, the parent of radium in radioactive equilibrium, with radium and its products, helium will be produced at a definite rate. Helium, however, unlike the radioactive elements, is permanent and accumulates in the mineral; hence if we measure the amount of helium in a sample of rock and the amount produced by the sample in one year we can find the length of time the helium has been accumulating, and hence the age of the rock. This method, which is due to Professor Strutt, may lead to determinations not merely of the average age of the crust of the earth, but of the ages of particular rocks and the date at which the various strata were deposited; he has, for example, shown in this way that a specimen of the mineral thorianite must be more than 240 million years old.

The physiological and medical properties of the rays emitted by radium is a field of research in which enough has already been done to justify the hope that it may lead to considerable alleviation of human suffering. It seems quite definitely established that for some diseases, notably rodent ulcer, treatment with these rays has produced remarkable cures; it is imperative, lest we should be passing over a means of saving life and health, that the subject should be investigated in a much more systematic and extensive manner than there has yet been either time or material for. Radium is, however, so costly that few hospitals could afford to undertake pioneerink work of this kind; fortunately, however, through the generosity of Sir Ernest Cassel and Lord Iveagh a Radium Institute, under the patronage of his Majesty the King, has been founded in London for the study of the medical properties of radium, and for the treatment of patients suffering from diseases for which radium is beneficial.

The new discoveries made in physics in the last few years, and the ideas and potentialities suggested by them, have had an effect upon the workers in that subject akin to that produced in literature by the Renaissance. Enthusiasm has been quickened, and there is a hopeful, youthful, perhaps exuberant, spirit abroad which leads men to make with confidence experiments which would have been thought fantastic twenty years ago. It has quite dispelled the pessimistic feeling, not uncommon at that time, that all the interesting things had been discovered, and all that was left was to alter a decimal or two in some physical constant. There never was any justification for this feeling, there never were any signs of an approach to finality in science. The sum of knowledge is at present, at any rate, a diverging not a converging series. As we conquer peak after peak we see in front of us regions full of interest and beauty, but we do not see our goal, we do not see the horizon; in the distance tower still higher peaks, which will yield to those who ascend them still wider prospects, and deepen the feeling, whose truth is emphasized by every advance in science, that "Great are the Works of the Lord."

THE ORIGIN OF THE EARTH'S LAND FORMATIONS

By Dr. C. D. PERRINE

ARGENTINE NATIONAL OBSERVATORY, CORDOBA

THE peculiar and very irregular distribution of the land and water areas of the earth's surface as well as their forms and constitutions have attracted attention since man has known of their existence as such. Explanations to account for some of these conditions have been made from time to time, but none has been wholly satisfactory and for some no explanation has been attempted. The object of this note is to put on record the chief points of a general theory which occurred to me some years ago, and which appears to explain satisfactorily a number of observed facts. It is recognized that the difficulties in the way of substantial proofs are very great. For this and other reasons of scientific caution, the hypothesis is presented tentatively for further study and future confirmation or rejection. It is my belief, however, that, in general and radical as it is, it will be confirmed, because some of the evidence is of considerable weight and I have so far found none which is prohibitory.

Several years ago, the principal points known at that time were placed (on a general invitation) at the disposal of a group interested in the progress of science and its dissemination, but as far as I know nothing has yet been published on the subject. These and other details will be given in a full discussion of the hypothesis which it is planned to publish if my impaired health permits.

The theory rests upon the possibility that the earth was bombarded in some past age by a meteoric swarm or swarms which came from a southerly direction. When the explanation first suggested itself, no facts were known which could throw light on this all-important point, the suggestion coming solely from two well-marked peculiarities of continental and mountain