LETTERS TO THE EDITOR.

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The Life-history of Radium.

IN a letter under the above title in NATURE of May 5, Mr. Whetham brings forward some results dealing with the hypothesis that radium is being produced from uranium. May I be permitted to state that I have been engaged during the last twelve months in an experimental examination of this hypothesis? In the paper in which the suggestion was made that radium may be being formed by the disintegration of a parent element possessing heavier atomic weight (Rutherford and Soddy, *Phil. Mag.*, May, 1903, p. 587), this sentence occurs:—"The point is under experimental investigation by one of us, and a fuller discussion is reserved until later." Mr. Whetham's letter makes it desirable that the results that have been obtained during the past year should be published.

Twelve months ago I purified a kilogram of uranium nitrate until the quantity of radium present was less than 10^{-13} gram. This was the limit of detection by means of the electroscope employed, using the maximum or equilibrium amount of accumulated radium emanation as the test for the presence of radium. It was arrived at by direct comparisons with the emanation from a standard milligram of radium bromide, by subdivision until its presence could no longer be detected. Unfortunately, owing to the large amount of radium in the laboratory, subsequently introduced for the purpose of the helium research, the electroscopes have been affected, and it is not possible at the present time to be sure of such minute effects as originally. But it may be stated that less than 10^{-11} gram of radium has accumulated in the kilogram of uranium during the past twelve months. This practically settles the question so far as the production of radium from uranium is concerned.

In a paper read recently before the Royal Society by Sir William Ramsay and myself, an experimental determination of the rate of change of radium was given. It was shown that rather less than one-thousandth part changes per year. The rate of change of uranium may be taken as a million times slower, since its radio-activity is a million times less; so that, in one kilogram of uranium nitrate, about 5×10^{-7} gram would change per year. The quantity of radium produced was less than 10^{-11} gram, so that the conclusion is arrived at that if uranium changes into radium, less than one-ten thousandth part of the theoretical quantity is produced during the first year's accumulation.

The result, of course, may be explained by assuming the existence of intermediate forms between uranium and radium. But from a general consideration of the whole question from the point of view of the disintegration theory, several such hypothetical forms, each with an extended life, must be assumed. So that unless modifications are made in the theory, which at present are not justifiable, the evidence may be taken as indicating that uranium is not the parent element of radium. The experiments will be continued from year to year with the kilogram of uranium nitrate. But as I am leaving England immediately, and shall be away several months, I take the opportunity of presenting the results of the unfinished research, and hope at a later date to give a fuller account.

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IN their communication to the Royal Society of April 28, Sir William Ramsay and Mr. Soddy by direct measurements determine the rate of decay of radium as one thousandth of the mass per annum, giving as the average life of the radium atom about one thousand years.

This rapid rate of decay, of course, renders it quite out

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of the question to assume that in the radium now existing on the earth we are dealing with the residue of a larger quantity reduced by decay to its present amount. If we carry backwards so great a rate of change we, in fact, arrive at the existence of such large amounts quite a few thousand years ago as to postulate a red hot earth almost within historical times. We are thus either compelled to assume that the rate of transformation observed does not apply generally to terrestrial radium, but only to radium separated by chemical treatment from pitchblende, or that the existing store of radium is derived by steady supply from some substance of greater atomic weight. The first hypothesis, in view of what is known as to the intimately atomic nature of radio-activity, may be dismissed.

That the probable source of radium is uranium is advocated by Prof. Rutherford in his book on radio-activity. From a conversation with Sir Oliver Lodge I gather that he also considers this not improbable. The reasons for it need not be given here.

Now if radium is derived from pitchblende, the rate of change of radium is a measure of the rate of change of pitchblende, supposing a steady state of supply and loss has been attained. This last condition I think we are entitled to assume, although doubtless from the mathematician's point of view a perfect equality would be improbable. But I will quote Prof. Rutherford ("Radio-activity," p. 334):—"Since radium has a short life compared with that of uranium the amount of radium produced should reach a maximum after a few thousand years when the rate of production of fresh radium—which is also a measure of the rate of change of uranium—balances the rate of change of that product."

Let us now assume as an approximation that from 1000 kilos. of uranium the yield of radium under the most favourable conditions would be one decigram. It may here be observed that the fact of pitchblendes varying in their content of radium is only what is to be expected under the conditions of preservation of the ore, exposed as it is to chemical attack, or, as Prof. Rutherford points out, to the action of percolating water. We have in seeking to learn the content of radium for our present purpose to take the maximum observed.

The one decigram of radium transforms into substances of lesser atomic weight at the rate of one-tenth milligram per annum. Now this is also the annual supply from 1000 kilos. of uranium. In other words, the uranium breaks down at the rate of $1/10^{10}$ part of its mass per annum. The average life of the uranium atom is according to this ten thousand million years.

In determining this average life from so short a period of observation we, of course, make the assumption that the death rate observed is an average one, and that a steady state is attained truly founded on the mean longevity of a vast number of individuals of varying ages, varying rates of loss of corpuscular temperature as well as of varying amounts of initial corpuscular energy, such conditions as would attend material evolution according to Prof. J. J. Thomson's fascinating book "Electricity and Matter." Similar assumptions must be made before we could deduce the average longevity of a vast population from a short period of observation of the death-rate.

On these assumptions an interval of time is indicated which may be considered a minor limit to the antiquity of matter in our part of the universe. For if the average life is really 10^{10} years, must we not assume that some of the atoms now expiring as uranium were existing ten thousand million years ago? Geological time, as we guess it, is but little more than a moment in the being of so great an era—as thirty-six seconds is to an hour.

Whether we will ever be able to obtain direct proof of so remote an antiquity is impossible now to say, but it is remarkable that the rate of change of thorium to thorium X affords the same average longevity for the atom of thorium as we arrive at on the data above for uranium, or again from the known rate of change of uranium to uranium X. Thus Rutherford gives 10^{-16} to 10^{-17} as the change-rate per second to thorium X. The change-rate 10^{-10} for a year's disintegration will be found to lie between these limits.

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Trinity College, Dublin, May 1.