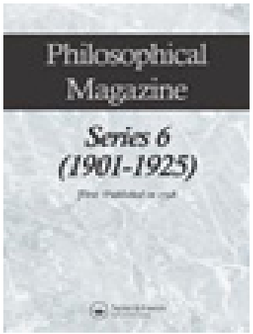

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XL. The ranges of the α particles from uranium

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From these surfaces the reflexion at the polarizing angle *sensibly disappears*. The image of the paraffin flame could be quenched by the operation of the polarizing nicol alone. When the quarter wave-plate and analysing nicol were introduced, α' and α could not be distinguished, the difference probably not exceeding ·05°, *i. e.* 3 minutes of angle.

In order to examine the reflexion when the quartz was in contact with a liquid of equal index, I had to mix alcohol with the benzole. The behaviour was then much the same as with glass of which the surface had been renewed by hydrofluoric acid. No precise measures could be taken, but the reflexion at 45° incidence seemed less than from the glass, though still easily visible. It spite of repeated trials with intermediate cleanings, it was difficult to feel sure that the residual effect might not be due to foreign matter, the more as differences could sometimes be detected between various parts of the surface *. Even if the surface could be regarded as clean on immersion, there is no certainty that a capiliary film of some sort might not be deposited upon it from the liquid. The cause of the small residual reflexion must remain for the present an open question.

XL. *The Ranges of the α Particles from Uranium.* *By* H. Geiger, *Ph.D., Lecturer in Physics, and* J. M. Nuttall, *B.Sc., Graduate Scholar, University of Manchester* †.

In connexion with a re-determination of the ranges of the α particles of a number of radioactive products, we have pointed out in a previous paper ‡ that there exists a quantitative relation between the range of an α particle and the transformation constant of the product from which it arises. This was arrived at by plotting the logarithms of the transformation constants against the logarithms of the ranges of the respective products. In this way approximately straight lines were obtained passing through the points representing the products of the Uranium-Radium and of the Actinium series. No details have yet been given for the Thorium series on account of insufficient data.

A certain difficulty remained as regards uranium. As Boltwood § has shown, this substance emits two α particles for one

* At the top of the plate, where it was attached to a handle, a slight invasion of gelatine (used as a cement) gave rise to a copious reflexion; but this film was easily visible in the air.

† Communicated by Prof. E. Rutherford, F.R.S.

‡ H. Geiger and J. M. Nuttall, Phil. Mag. vol. xxii. p. 613 (1911).

§ B. B. Boltwood, Amer. Journ. of Sci. vol. xxv. p. 269 (1908).

from each of the subsequent products, and this has been confirmed by the scintillation method by Geiger and Rutherford *. This may be ascribed to the existence of two successive α-ray products, or to the simultaneous emission of two α particles in the disintegration of each atom. The latter hypothesis is excluded by the experiments of Marsden and Barratt †, who found no evidence that two α particles were emitted simultaneously. It seems therefore probable that there exist two successive products each of long period which cannot be separated by ordinary chemical methods. To settle definitely whether this is the case, experiments have been made which will be described in this paper, to determine accurately the ionization curve of the α particles from a very thin film of uranium. For purpose of comparison, curves were taken under exactly the same conditions for films of ionium and polonium. Assuming that there are present in uranium two α-ray products whose difference of range is at least one millimetre (which means that the two periods differ by about a factor 10), this would affect the ionization curve to such an extent that it would be distinguishable from the ionization curves of simple α-ray products like ionium or polonium.

The method of determining the ionization curve of an α particle, originally devised by Bragg ‡, consists in the measurement of the ionization produced by a parallel pencil of α rays in a shallow ionization vessel placed at different distances from the source. This method can easily be applied if the material can be obtained as a very thin film of high activity. Since, however, uranium shows only a very low activity it was necessary to modify the original arrangement of Bragg. In the first place, it seemed advisable to make the dimensions of the apparatus as large as possible to enable the use of films of very large area. In the second place, it appeared advantageous to combine the ionization vessel and the measuring instrument by using an electroscope which has a small capacity and allows the accurate measurement of very minute ionization currents.

The arrangement used in the experiments will be seen from fig. 1. The main part of the apparatus consisted of two large bell-jars AA and BB, separated by a brass plate CC. A large number of holes—about 250—each 3·7 mm. in diameter and 8 mm. high, forming a circular "grid" of

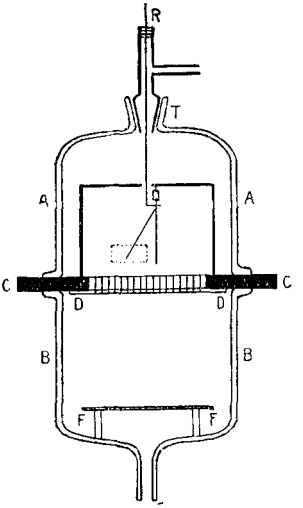
* H. Geiger and E. Rutherford, Phil. Mag. vol. xx. p. 691 (1910).

† E. Marsden and T. Barratt, Proc. Phys. Soc. vol. xxiii. p. 367 (1911).

‡ W. H. Bragg and R. D. Kleeman, Phil. Mag. vol. viii. p. 726 (1904); vol. x. p. 318 (1905).

10 cm. diameter, were drilled through the brass plate CC. An exactly similar but much thinner brass plate DD could be screwed on to the lower side of the plate CC. Between

Fig. 1.



these two plates a thin and uniform sheet of mica of stopping power equivalent to 8 mm. of air was placed and fixed down air-tight. On account of its position between the metal grids the mica was secured against breakage, and was then easily able to withstand an excess of 20 cm. pressure from either side; this difference of pressure was frequently necessary in the course of the experiments. The lower bell-jar BB contained the active film FF at a distance of 9·8 cm. from the mica. On account of the metal grid only the α particles emitted at angles less than 20 degrees to the normal could pass through the mica into the upper bell-jar which contained the electroscope. The latter was cylindrical in shape and was 8 cm. high and 10·5 cm. in diameter. It could be charged from outside through the wire R which could be rotated by means of the ground-glass joint T.

In the experiments the upper bell-jar was first completely exhausted and then filled with hydrogen up to a pressure of about 9 cm. of mercury. The use of hydrogen is preferable to air since, according to Taylor * and others, the rise of the ionization curve is more pronounced in the former gas than

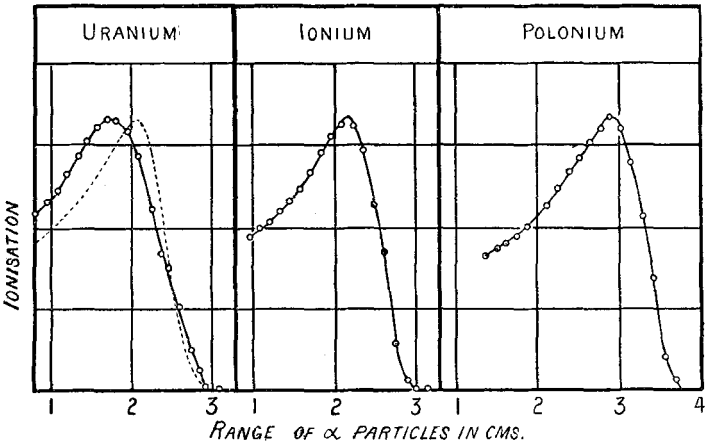
* T. S. Taylor, Phil. Mag. vol. xviii. p. 604 (1909); vol. xxi. p. 571 (1911).

in the latter. When filled with hydrogen to 9 cm. pressure the depth of the ionization vessel corresponded to 2·5 mm. of air at atmospheric pressure, since the α particles had to travel on an average through about 8·5 cm. in the electroscope before they were stopped by the upper plate. The ionization at different parts of the range of the α particles could be measured by varying the pressure in the lower bell-jar. When the latter was completely exhausted the range of the α particles on entering the electroscope was only diminished by about 8 mm., the distance corresponding to the stopping power of the mica. When the pressure in the lower vessel exceeded 25 cm., the α particles were completely stopped and the ionization then observed in the electroscope was due to the natural effect only. By measuring the ionization for different pressures in BB between the above limits a complete ionization curve was obtained. A film of uranium which contained ·4 mgr. per square cm. gave an easily measurable effect—about ·3 div./min. corrected for natural leak.

The films used in the experiments were prepared in the following way. A round glass plate of about 15 cm. diameter was carefully ground on one side by means of very fine emery. Pure uranium oxide which was well powdered was then distributed uniformly over the plate by rubbing down with the finger. In this way very thin and uniform films were obtained which contained approximately ·4 mgr. a square cm. In all cases the uranium X was first separated by the "iron method" in order to avoid any effects due to soft or hard β rays. For the purpose of making a comparison under practically identical conditions of the ionization curves of uranium and ionium, a trace of highly concentrated ionium was mixed with about a hundred times the quantity of uranium oxide. The materials were dissolved in acid in order to secure their complete mixture; the solution was then evaporated to dryness and the residue changed into oxide. This material was then distributed on a glass plate in exactly the same way as described above for the pure uranium oxide. On account of the presence of the ionium, this uranium film was now about 30 times as active as an ordinary pure uranium film. Another uranium film containing a trace of polonium was also prepared in a similar way. In this case the activity of the film was about 28 times greater than that of a pure uranium film. This method of preparing the films ensured that the absorption, if any, in the matter itself would have affected the ionization curves in the three cases in exactly the same way.

Three typical curves are given in fig. 2, the ionization being plotted against the range of the α particles. Corrections

Fig. 2.



were made for the natural leak and also for the effect due to the uranium in the case of the ionium and polonium films. All three curves are typical of the ionization curve due to a parallel pencil of α particles in hydrogen. But while the curves for ionium and polonium completely agree with each other, the curve for uranium is distinctly different. In the latter case the maximum is not so sharply defined and the curve shows a much slower fall from the maximum towards the end of the range. To make this clear, the curve for ionium (see dotted line) is superposed on that of uranium, the ends of the two curves being made to coincide. The same difference between the curves was also brought out when the ionization was measured in hydrogen at a higher pressure or in air, or when slightly thicker films were used. As has already been pointed out, this cannot be due to the thickness of the film or to any other experimental cause.

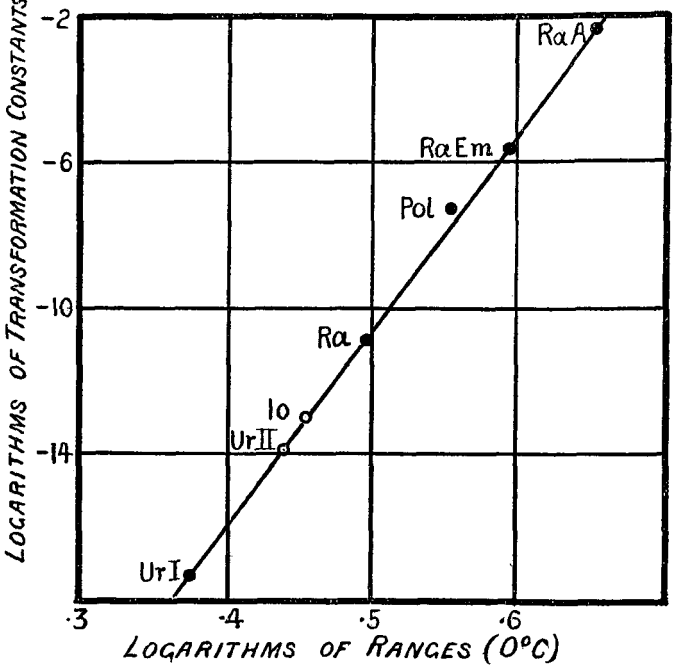
It seems, therefore, necessary to conclude that there exist two α-ray products in uranium which possess a slight difference of range. A determination of the difference of range of the two products could be made by comparison with a theoretical curve obtained by adding together two simple ionization curves of known difference of range. In this way it was found that by compounding two ionium or two polonium curves which were shifted relative to each other by 4 mm.,

a curve was obtained which agreed completely with the experimental curve for uranium.

Uranium consists, therefore, of two α-ray products whose ranges are 2·9 and 2·5 cm. in air at atmospheric pressure and at a temperature of 15° C. The value of the range of the α particles from uranium obtained by other observers and also previously by us (2·72 cm.), was obviously an average value of the two figures given above. No evidence has been obtained in these experiments of α particles of range 1·6 cm. as suggested recently by Friedmann *.

The above figure for the range of uranium, viz. 2·5 cm., is in much better agreement with the straight-line relation mentioned above between transformation constant and range, and fixes the straight line with a much higher degree of accuracy (see fig. 3). This is of special interest, since it

Fig. 3.



enables us to calculate the period of ionium and of the second product in uranium (uranium II.) with greater certainty than has hitherto been possible.

* F. Friedmann, *Wien. Ber.* cxx. p. 1361 (1911).

Uranium I. therefore, which has a period of 5×10^9 years, emits α particles of range 2·5 cm. in air at atmospheric pressure and at 15° C., and is followed by another α-ray product, *uranium II.*, which has a period of about 2×10^6 years and emits α particles of range 2·9 cm. It is thus clear that in purified uranium preparations two successive α-ray products are present, differing in atomic weight by 4 units. These products must be very closely allied in chemical properties, for the experiments of many observers, amongst whom may be mentioned Boltwood and Soddy, have shown that it is impossible to reduce the α-ray activity of uranium by any chemical methods. A similar striking chemical affinity has been observed in the two elements thorium and ionium and also in a few other cases. Since the ratio of the two transformation constants of the two products in uranium is of the order of 10^3, the amount of uranium II. in a gram of uranium is about one milligram. The presence of this small quantity of uranium II., differing only by 4 units from the atomic weight of uranium (238·5), can only affect a determination of the latter in the third decimal place.

Taking the range of the α particles from ionium as 3·00 cm. at 15° C. (=2·84 cm. at 0° C.), we find by interpolation from fig. 3 that it has a period of about 200,000 years, instead of the million years previously deduced.

Using the figures given in our previous paper, Swinne * has recently shown that the relation between range and transformation constant can be expressed in another form, but we postpone any discussion of this until the experiments on the ranges of the α particles from the products in the thorium series which are now in progress have been completed.

We wish to express our thanks to Prof. Rutherford for his kind interest and help in these experiments.

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Physical Laboratories.

XLI. *Notices respecting New Books.*

A Course of Plane Geometry for Advanced Students. Part II. By Clement V. Durell, *M.A.* Macmillan & Co.: London, 1910.

IN the first part of this important work Mr. Durell dealt with the geometry of the straight line and circle. He now continues his method of treatment to the geometry of the conic. The nature of the treatment cannot be better described than in the following

* R. Swinne, *Phys. Zeitschr.* xiii. p. 14 (1912).