XI. The γ rays of polonium, radium, and radioactinium

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112 Dr. Russell and Mr. Chadwick on the γ Rays of
one mm. deflexion is

$$R = \left(\frac{3 \cdot 23 \times 0 \cdot 080}{12,100 \times 0 \cdot 393} = 0 \cdot 000054 \right) \text{ electromagnetic unit.}$$

Hence this experiment indicates that in solid mercury there is no Hall coefficient larger than $0 \cdot 000011$ electromagnetic unit, which is about one-fourth that of tin.

After this investigation was begun, Alterthum * published some theoretical work indicating the absence of a Hall effect in liquids; but the experiments described here show that the observations which have been made on liquid mercury cannot be adduced to support that theory.

I am indebted to Professor Barnett for proposing this investigation and for many valuable suggestions. For similar suggestions I am also indebted to Professor A. W. Smith.

The Physical Laboratory,
Ohio State University,
June 1, 1913.

XI. *The γ Rays of Polonium, Radium, and Radioactinium.*
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THE work, an account of which is given in this paper, is a continuation of that already described in two previous communications ‡. In the first of these it was shown that when the α -rays of radium C impinge upon plates of different materials, a small but definite amount of γ -radiation is produced. The amount of this radiation was, however, too small to permit of analysis. Later we showed that strong preparations of ionium and of radiothorium, when freed from all bodies emitting β - and γ -rays, emitted a small quantity of γ -radiation. For various reasons the radiation emitted by radiothorium was not analysed. Analysis of the radiation of ionium, however, showed that it consisted of three types of rays varying widely in penetrating power and in intensity. A small quantity of β -radiation, too large to be ascribed to thorium products, but too small to be analysed, was found also to accompany the γ -radiation from ionium.

* *Ann. der Phys.* no. 15, 1912, p. 933.

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

‡ J. Chadwick, *Phil. Mag.* vol. xxv. p. 193 (1913); J. Chadwick & A. S. Russell, *Proc. Roy. Soc. A.* vol. lxxxvii. p. 489.

The results obtained with ionium raised the question whether this γ -radiation is emitted by the disintegrating atoms themselves, *i. e.* by the ionium, or by the thorium with which it was mixed and from which it could not be separated. Had the separation of thorium from ionium been possible, this question would not have been a difficult one to answer, but, as is well known, this cannot be done. To attack this problem therefore, and to extend our knowledge of the nature of the γ -rays excited by the α -rays, we have continued our work by investigating the γ -rays emitted by polonium, by the element radium itself, and by radioactinium.

The five bodies we have investigated, *viz.* ionium, radiothorium, polonium, radium, and radioactinium, expel, in addition to their α -rays, a small quantity of γ -radiation. It seems probable therefore that all α -ray bodies, when completely freed from all products and impurities emitting β - and γ -rays, emit a measurable quantity of γ -radiation, provided the quantity of material under investigation is sufficiently great. In the γ -ray electroscope used by us, which is a large one of the ordinary type with a very thin window through which the rays pass, a quantity of about 1 milligramme of radium, or a quantity of another body, expelling per second the same number of α -particles, is necessary to obtain measurable effects.

We found that the β -radiation from ionium under our experimental conditions was only about 10 per cent. in intensity of the γ -radiation, and a result of a similar nature has been found with polonium. These α -ray bodies emit, therefore, a very small amount of β -radiation. There are other α -ray bodies, however, such as radium, thorium X, and radioactinium, which emit considerable quantities of β -radiation. An investigation of the γ -rays of one of these, for instance radium, is therefore likely to show that it emits γ -rays corresponding to its β -rays, as well as γ -rays produced by the α -rays.

The great difficulty in this research has been to obtain a sufficiently large quantity of polonium. By the kindness of Professor Rutherford the strongest source of polonium available in the laboratory was obtained, but the intensity of the γ -rays was disappointingly small. For this reason we were unable to obtain, either in accuracy or in detail, the results we hoped for when the work was commenced, and for which the methods described in this paper were worked out.

Preparation of pure Polonium and of Radium D and E.

The method of separation of polonium which we employed consisted of a combination of ordinary chemical methods, electrolysis, and volatilization. As it was possible by these methods to prepare at the same time radium D and radium E in the pure state, and as it was necessary to do this for another research, a detailed account will now be given of the separation of all of these bodies, though there is nothing essentially new either in principle or in details in the methods employed.

Preliminary experiments were carried out on an old preparation of radium (D+E+F) containing, as impurity, lead sulphide. The object of these experiments was to obtain each of these substances in the form of a thin film on a metal as nearly as possible in quantitative amount, and free from active and inactive impurities. When these experiments were completed operations were carried out on larger quantities.

The largest source of polonium in the laboratory was the accumulation of radium (D+E+F) in a preparation of 31 milligrammes of radium bromide which had been sealed up and untouched for six or seven years. This material was dissolved in hot water containing just enough HCl to effect solution. To this was added a solution containing 1 milligramme lead chloride and the whole evaporated to about 10 c.cm. A plate of copper well polished on both sides was rotated in this solution for about two hours. Preliminary experiments had shown that under these circumstances about 95 per cent. of the polonium is deposited on the copper. A fair proportion of radium E is also deposited with it, but no radium D if lead be present. The copper plate was then removed, carefully washed, and set aside.

The radium solution was diluted, and heated, and a solution of H_2S added to it in excess. This precipitated as sulphides all the copper which had been previously dissolved off the electrode and also the lead which had been previously added. The precipitate contained the whole of the radium D, and all the radium E and polonium not deposited on the copper. It was dissolved in HNO_3 , the solution evaporated to dryness, and the material redissolved in hot water containing a little HCl. To obtain the radium D from this solution it was treated as follows. Three milligrammes of aluminium in the form of chloride were added to the solution, and then ammonia in excess. This precipitates everything except the copper. It is necessary to remove the copper at this stage since the subsequent operation of separating radium D from

radium E by depositing the latter on a plate of nickel does not lead to satisfactory results when copper is present. The aluminium is added to act as a nucleus for the small quantity of lead hydroxide precipitated by the ammonia. The precipitate of lead and aluminium was then dissolved in the minimum quantity of HCl and evaporated to a volume of a few cubic centimetres. A plate of polished nickel was rotated in this solution for half an hour and then removed. This removes from the radium D practically all the radium E and polonium.

A small quantity of nickel goes into solution. The solution is then treated with excess of ammonia. The nickel in the solution is not precipitated by the ammonia, but the lead and the aluminium containing the radium D are precipitated quantitatively. This precipitate was then filtered off and used as source on the filter-paper. It is not advisable, nor is it for any purpose necessary, to separate the lead and the radium D from the aluminium. Two preparations of radium D prepared in this way from two different quantities of old radium were used by Rutherford and Richardson in their work on the γ -rays of this substance*.

The radium E grown from these radium D preparations is separated as follows. The preparation is dissolved in the minimum quantity of HCl, evaporated till the solution contains a few c.cm. only, and a clean nickel plate varnished on one side is rotated in it for half an hour. This removes nearly all the radium E but no radium D whatever. The radium E deposited on nickel acts as a convenient source of that body. If it is necessary to have it deposited on another metal, it is first deposited on nickel and then transferred to the other metal by volatilization. The details of this operation are given below. To the solution from which the radium E has been removed ammonia in excess is added. The precipitated lead and aluminium containing the radium D are filtered off from the nickel and used as a source on the filter-paper.

The large quantity of polonium on the copper plate was freed from the radium E deposited with it by volatilization in air. Preliminary experiments on the volatilization of these bodies showed that in air at a temperature of 900° C. polonium is completely volatilized in a short time, while at this temperature little or no radium E is volatilized. This fact was made use of in separating the polonium from the radium E. To volatilize radium E in air it was found

* E. Rutherford & H. Richardson, *Phil. Mag.* vol. xxvi. p. 324 (1913).

necessary to employ a temperature greater than 1100° , but in hydrogen it can be volatilized in a short time at 900° . The second of these facts was used in transferring radium E from metal to metal in connexion with the work of Rutherford and Richardson*.

The apparatus used in volatilizing these substances is shown in the figure.

ABC is a thick porcelain tube, 25 cm. in length and 2.4 cm. inside diameter, closed at one end B. The other end is closed by an ebonite cork D through which a brass cylinder passes centrally. The diameter of this cylinder is

* Phil. Mag. vol. xxvi. p. 324 (1913).

11 mm., and its end EF is about 3 to 4 cm. from the end of the porcelain tube. This inner cylinder can be kept cool, when the outer is heated, by circulating cold water through it, the water running in at G and out at E. A long tube of quartz J passes through D and reaches almost to the bottom of the porcelain tube. This enables the apparatus to be filled with hydrogen if required. The hydrogen passes out of the tube through K. The active material deposited on a metal was placed at B. The metal on to which it was to be volatilized was wrapped round the cooled tube as high as E'F'. A cap of the same material covered the end of the tube EF.

The tube ABC was placed in a furnace so that the temperature of three or four centimetres of it at the end B was about 900°, the tube being water-cooled. The active plate containing the polonium and the radium E was placed at B. Aluminium was wrapped round the cooled tube. After two hours the volatilization was stopped. It was then found that the copper plate, now covered with a thin film of oxide, was quite free from polonium and contained radium E only. The aluminium, on the other hand, contained no radium E, for it emitted very little β -radiation and this did not decay with time. The greater part of the polonium was deposited on the cap which had been wrapped round EF. Some was deposited on the portion E'EFF' in the vicinity of the end of the tube.

Many transference experiments were carried out in this way with polonium. When small quantities were dealt with, if the experiment were carefully carried out, there was usually not much loss of material in volatilizing from one metal to another, about 95 per cent. of material being obtained on the second metal. It was more difficult to say what proportion was obtained when large quantities were used.

In transferring radium E from one metal to another the experiment was carried out similarly. Radium E was placed at B, the same temperature was employed, but the volatilization was conducted in a gentle stream of hydrogen gas. The transference was never quantitative, but the loss of material was rarely more than 10 per cent. of the whole.

The γ -radiation of Polonium.

The preparation of polonium deposited on aluminium foil was mounted on a cardboard frame and suspended between the pole-pieces of a powerful electromagnet. The faces of the pole-pieces were 10 cm. $\times$ 16.5 cm. and were 7 cm. apart.

They were covered with thick cardboard to minimise diffuse reflexion of β - and γ -rays from them. The electroscope was of the ordinary type, 15 cm. $\times$ 10 cm. $\times$ 10 cm., and was placed at the end of the pole-pieces. In the side against the pole-pieces was cut an opening 8 cm. by 8 cm., which was covered with aluminium foil .0013 cm. thick. The distance of the polonium preparation from this side of the electroscope was 5 cm. The strength of the magnetic field usually employed to deviate the β -rays completely was about 1500 gauss. Under these conditions the polonium preparation gave a leak of 6 scale-divisions per minute when the magnetic field was applied. As no α -rays could possibly enter the electroscope, and as the preparation was free from other products, this leak must be due to the γ -rays of polonium itself. The absorption of the radiation by thin sheets of aluminium was determined, and the curve obtained showed the presence of one type of radiation only. The mean value of $\frac{\mu}{D}$ (cm.)⁻¹—the absorption coefficient divided by the density

—obtained from several determinations was 230. This value corrected for obliquity of the beam becomes 215. Although the polonium was deposited on several different metals, this type of radiation was always obtained. It cannot, therefore, be due to the impact of the α -particles against the aluminium, and must be due to the polonium atoms themselves.

If a harder type of radiation is emitted by the polonium, one would expect it to be of about the same penetrating power as the soft γ -rays of radium D. In order that this point might be more thoroughly investigated, Professor Rutherford kindly allowed us to use the electroscope filled with methyl iodide described by Rutherford and Richardson*. Some slight evidence of the existence of a harder type was obtained, but its intensity was only about 2 per cent. of the natural leak. This evidence cannot, therefore, be regarded as definite, and if a harder type does exist it must be very small in intensity compared with the type described above, and would require powerful preparations to permit of its analysis.

When the magnetic field was not applied the leak in the electroscope was increased about 1 division a minute. This difference is due to β -rays emitted probably by polonium, for different preparations of polonium gave a β -radiation proportional in amount to the γ -radiation. It is possible, but unlikely, that the same proportion of radium D and E would be present in preparations of polonium which had been

* Phil. Mag. vol. xxvi. p. 324 (1913).

subjected to different processes of purification. This β -radiation was soft, but its amount was too small to be investigated further. It was, however, much more penetrating than the β -rays described by Bumstead and McGougan*, which were shown to be completely absorbed by 0.64×10^{-4} cm. aluminium.

Quantitative determination of the Intensities of strong sources of Polonium.

The polonium was next transferred from aluminium to different metals to see whether or not the α -rays of polonium set up γ -radiation in these metals. It was necessary, therefore, to have a means of measuring accurately by α -rays the strength of the sources employed. The quantities of polonium to be measured varied widely in intensity, from about that in equilibrium with 0.1 mg. radium to that in equilibrium with 2 mg. The usual methods of measuring bodies which expel α -rays, *e. g.* the scintillation method of counting particles, are much too sensitive for quantities of this magnitude. The ionization current produced by such large amounts is, however, sufficiently great to be measured by a galvanometer, and this was the method employed. To enable quantities of widely different magnitudes to be measured without change in the apparatus, a balance method was used which consisted simply in sending a current through a galvanometer in the opposite direction to the ionization current. The current was provided by a storage-cell and could be varied by means of a resistance-box. We found in this way that the actual amount of polonium separated by us from 18 mgrms. of radium metal after six years' growth was that in equilibrium with 1.3 mgrms. of radium. The theoretical amount, provided the polonium had been separated quantitatively, is 3.6 mgrms., taking the period of radium D as 16.5 years. There is a serious discrepancy between these numbers. We found a discrepancy of a similar order between the theoretical and experimental amounts of polonium separated from 5 mgrms. of old radium which had been left untouched for seven years. We cannot offer any adequate explanation of these results. It is most unlikely that we obtained a third only of the total quantity of polonium, since the separations were repeated without obtaining a further quantity of polonium. On the other hand, Antonoff's method of determining the period of radium D was equivalent to the above, and his value used in our calculation is very similar to that obtained previously by Meyer and von Schweidler.

* Bumstead & McGougan, *Phil. Mag.* vol. xxiv. p. 462.

Excitation of γ -rays by the α -rays in Copper and in other metals.

The main quantity of polonium was transferred from aluminium to copper by dissolving the aluminium in HCl, evaporating the solution to dryness, dissolving the aluminium chloride in water, and rotating a clean copper plate varnished on one side in the solution for an hour. The γ -radiation from this plate was then analysed in the usual way.

Both in penetrating power and in intensity, the radiation from polonium on copper was different from what it had been when the polonium was deposited on aluminium. The intensity measured under the same experimental conditions was, for equal quantities of polonium, about three times greater on copper than on aluminium. This amount varied, however, according as the copper oxide and chloride on the surface of the copper was quite dry or not. Two types of radiation were found to be present. One was the same in intensity and penetrating power as that emitted from

aluminium, with a value of $\frac{\mu}{D} = 215$, the other giving a value $\frac{\mu}{D} = 1300$ about. This new radiation must be due to excitation in the copper by the α -rays. It is possibly the characteristic radiation of copper in series L.

The active material was next transferred back to aluminium by volatilization, and the intensity measured again. No other radiation except that having a value of $\frac{\mu}{D} = 215$ could be detected, and the copper was inactive. Part of the main quantity of polonium was then deposited on platinum foil and the radiation investigated. No evidence of an excited radiation was obtained. The rest of the polonium was volatilized on to lead foil. The amount and absorbability of the radiation in this case were approximately the same as when the polonium was deposited on aluminium, except that the absorption produced by the first thickness of aluminium was rather greater than before. The difference, however, was 0.2 div. per minute only, and therefore too small to be regarded as definite.

It is thus seen that when polonium is deposited on metals of high atomic weight like platinum and lead, the excited radiation, if produced at all, is small compared with that excited in an element of low atomic weight similar to copper.

Experiments with other metals were not carried out owing to the difficulty of measuring the small effects to be obtained with the quantity of polonium at our disposal. Such experiments can be most conveniently carried out with an α -ray body which can be obtained in considerable quantity, such as radium C. The experiments with polonium show that an excited radiation can be produced by α -rays in at least one metal, a phenomenon that has already been found with radium C. In this connexion it may be mentioned that recently Rutherford and Richardson*, using a source of radium C on a nickel plate, found that the α -rays produced in nickel a soft γ -radiation probably belonging to series K.

The γ -rays of Radium.

Hahn and Meitner† found that radium, completely freed from all its short- and long-lived products, emitted a radiation of a very soft type having a coefficient of absorption μ in aluminium of about 312 (cm.)^{-1} . This result was confirmed by Kolowrat‡, who found a value of μ of 200 (cm.)^{-1} . This radiation is a β - and not a γ -radiation, for it is capable of being deflected by a magnetic field, and has been shown to consist of two groups of homogeneous rays expelled with velocities 0.52 and 0.65 of the velocity of light. The amount of this radiation measured in the ordinary way was about 2 per cent. of the total β -radiation of radium in equilibrium with its products. So far, however, no one has carried out an investigation to determine if a γ -radiation accompanies this β -radiation.

Several investigators, however, have pointed out that if a radium solution, from which the radium D, E, and F have been removed, be evaporated slowly to dryness in such a way that all the emanation is expelled and all the short-lived products have time to decay, the intensity of the γ -radiation is about 2 per cent. of the initial activity, if the rays are measured through a sufficient thickness of material to absorb the β -rays completely. It was natural in the early experiments to attribute this radiation to the presence of some radium C which had not been removed by the methods employed. In the light of subsequent work, it is possible that this radiation, or at least a part of it, is emitted by the radium atoms themselves, and is not to be ascribed to radium B and C.

* Rutherford & Richardson, *Phil. Mag.* vol. xxv. p. 722.

† Hahn & Meitner, *Phys. Zeit.* vol. x. p. 741 (1909).

‡ Kolowrat, *Le Radium*, vol. vii. p. 269 (1910).

An investigation of the γ -radiation of a quantity of radium at its minimum α -ray activity has therefore been carried out by us.

A radium solution, from which the radium D, E, and F had been completely removed some days previously, containing about five milligrammes of radium bromide, was heated on a water-bath for six hours, the amount of solution being kept constant by adding water. We experienced some difficulty in keeping the radium in solution, and had to add some HCl to prevent the radium from being precipitated. Every twenty minutes a little air was bubbled through the solution to remove any emanation not otherwise expelled. After about six hours' boiling the solution was evaporated to dryness as rapidly as possible, first on a water-bath and later at a temperature of about 200° . The evaporating dish containing the radium was then placed at a distance of 10 cm. from the side of the electroscope between the pole-pieces of the magnet. Measurements of the β - and the γ -ray activity were made through various thicknesses of aluminium until the growth of radium B and C interfered with the measurements. Several successful experiments were made, and it was found that the activity of the radium was reduced to about the same amount each time. The β -ray activity of the radium immediately after evaporation was nearly 250 div. per min., and the γ -ray activity 4 div. per min. Although measurements of the rise of the activity of the preparation showed that little or no radium B or radium C was present initially, yet absorption measurements of the β -radiation indicated the presence of a hard radiation in addition to the soft. The amount of this hard radiation was about 10 div. per min., and it had an absorption coefficient of about 20 (cm.)^{-1} in aluminium. We had hoped that absorption measurements of the β -radiation would afford a test of the purity of the radium, but the presence of these penetrating β -rays prevented this.

Some results will now be given which show that the γ -radiation measured by us was due to radium, and not to its products. In one experiment the β -rays through a thickness of 0.057 cm. aluminium varied from 9.4 to 21.5 during the course of an experiment, the γ -rays in the same time and through the same thickness varied only from 2.8 to 3.5. In another experiment the β -rays increased from 10 to 17 through the same thickness of aluminium as above, while the γ -rays increased only from 3.4 to 3.6. Even if the hard β -rays had been due to radium C the γ -rays could not be due to it, and had radium C been present there would have been an initial decay.

The absorption of the γ -radiation of radium at the time of its minimum activity was compared with that of radium in equilibrium with its products, radium A, B, and C. In the first column of Table I. below is given the thickness of aluminium, in the second are the intensities of the radiation from radium in equilibrium with radium A, B, and C, through these thicknesses, where the initial intensity has been put at 100, in the third the relative intensities of the γ -radiation from radium at its minimum activity. The table shows that the γ -rays of radium itself are much less penetrating than those of its products radium A, B and C.

TABLE I.

Thickness of Aluminium (cm.).	Intensity of γ -rays from Ra + Ra(A + B + C) in equilibrium.	Intensity of γ -rays from radium itself.
0.08	100	100
0.57	97.6	87
1.33	94.5	78
2.66	—	72
3.23	91.3	—
1.0	81.6	62
1.3	—	56
2.0	73.9	45
2.3	—	33

The intensity of the γ -radiation of radium was about 1 to 1½ per cent. of that of radium and its products in equilibrium measured through 0.1 cm. of aluminium. This percentage would be less if the measurements were conducted through a greater thickness of aluminium or of lead.

Absorption measurements of the radium γ -rays by small thicknesses of aluminium showed the presence of a very soft type of radiation which had a value of $\frac{\mu}{D}$ between 100 and 150. The amount of this type varied between 1.5 and 2.5 div. per min. according to the distribution of the active material. Owing to the growth of emanation and of radium B and C, the γ -ray activity began to rise steadily after an hour. Emanation also diffused into the electroscope and increased the natural leak. Consequently it was difficult to make accurate measurements, and though it can be said definitely that radium emits three types of γ -radiation, the absorption coefficients given are only approximate. The softest type gave about 2 div. per min., and had a value of

$\frac{\mu}{D}$ between 100 and 150. The amount of the intermediate type was about 1 div. per min. and $\frac{\mu}{D}$ about 6. The hardest type gave about 3 div. per min. and gave $\frac{\mu}{D}$ about .09 or .10.

By comparison with the radiations from other bodies, and from the proportion of the different types, it would appear that the two harder types are connected with the β -radiation while the softest type is due to α -rays. It is of course possible that the intermediate type is also due to α -rays.

Radioactinium.

An examination has also been made of the radiations of radioactinium. Hahn and Meitner* showed that, besides α -rays, the body emitted soft β -rays, and a radiation which was either a hard β -radiation or a soft γ -radiation. An actinium preparation was taken and its γ -radiation was found to be about 23 div. per min. The radioactinium was separated from this by chemical operations and its radiations examined. We found that besides the soft β -rays described by Hahn and Meitner, there was a γ -radiation of about 5.5 div. per min. This γ -radiation was found to consist of two types, the absorption coefficients of which were only approximately determined. The measurements showed that these types were very slightly harder than the two hard types emitted by ionium, the values of $\frac{\mu}{D}$ (cm.)⁻¹ being about 8 and 0.1.

During this investigation we thought we had succeeded in showing that radioactinium is complex, and in a letter to 'Nature' of 26th December, 1912, we stated that radioactinium consists of two products, the second of which has a half value period of about 12 hours. Subsequent work showed that the actinium preparation we had been using contained a small amount of either mesothorium or radiothorium. This fact, and also the nature of the chemical properties, suggested that the new product was really thorium B, although the tests for thorium emanation indicated that the amount of the contamination with thorium products was not sufficient to vitiate the results. However, as both of us are leaving Manchester, and as neither of us will have an opportunity of continuing the work for some time, we think it is better to withdraw our statement of the complex nature of radioactinium.

* Hahn & Meitner, *Phys. Zeit.* vol. ix. p. 897 (1908).

Summary.

(1) Methods of separating radium D, radium E, and polonium in the pure state in a form suitable for physical work are described in detail.

(2) The γ -radiations from polonium, from radium, and from radioactinium have been investigated. Polonium emits γ -radiation of one type only, having a value of $\frac{\mu}{D} = 215(\text{cm.})^{-1}$.

This radiation is due to the polonium itself, and is not due to impact of the α -rays of polonium against the metal on which it is deposited.

The α -rays of polonium are able to excite a soft γ -radiation in copper, though not to an appreciable extent in platinum or in lead. This excited radiation in copper is possibly the characteristic radiation of copper in Series L.

A very small quantity of β -radiation is also emitted by polonium.

(3) Radium itself freed from its products has been found to emit γ -rays. This γ -radiation appears to consist of three types, one of which is much softer than the other two. The softest type has a value of $\frac{\mu}{D}(\text{cm.})^{-1}$ in aluminium of about

130, and the other two types of 6 and 0.1. The intensity of the γ -radiation from radium itself is about 1 to $1\frac{1}{2}$ per cent. of that of radium in equilibrium with its short-lived products.

(4) The quantity of polonium separated from two different quantities of old radium of known age was about two to three times smaller than is to be expected if the separation were approximately quantitative and the period of radium D were 16.5 years.

(5) Radioactinium emits two types of γ -rays, the value of $\frac{\mu}{D}(\text{cm.})^{-1}$ in aluminium of one being about 8, and that of the other about 0.1. The results given in a previous preliminary communication regarding the existence of a new product in the actinium series are withdrawn.

We have to express our warmest thanks to Professor Rutherford for placing at our disposal the apparatus and valuable radioactive material necessary for the carrying out of the work, and for his stimulating interest and advice at all times.