THE γ-RAYS OF IONIUM

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1. Introduction

The only previous investigation of the γ-rays of ionium is that of Chadwick and Russell(1) in 1913. Using an ordinary electroscope, with a magnetic field to deflect β-rays, they found a weak γ-ray effect. By absorption measurements in aluminium the γ-radiation was analysed into three components with μ/ρ in aluminium of 0·15, 8·35 and 700 g.$^{-1}$ cm.^{2}. These have since been provisionally identified(2) as the K, L and M characteristic radiations. It is difficult to understand how K-radiation could be emitted unless it were produced by a nuclear γ-ray of sufficient energy to excite it. In this paper is reported a detailed analysis of the hard component of the γ-radiation from ionium.

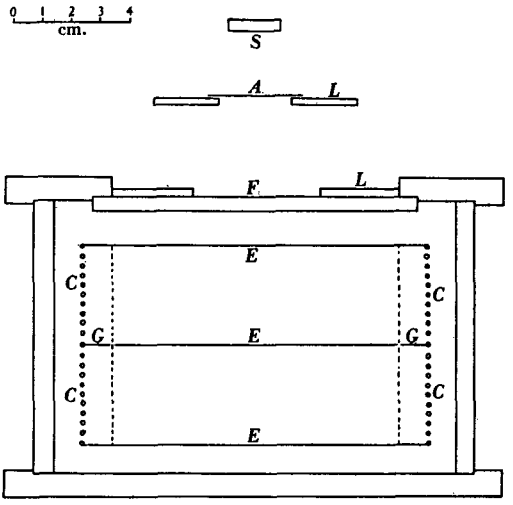


Fig. 1.

2. Experimental arrangement

The experimental arrangement is shown in Fig. 1; it was symmetrical about an axis in the plane of the paper. The source S was contained in a sealed aluminium dish, 1·5 cm. internal diameter, and was placed close to the ionization chamber to give measurable intensities of γ-radiation. Lead screens L, L were used to cut off the more oblique rays and the absorbing sheets were placed at A. The ionization chamber was of steel, with a window F of aluminium 5 mm. thick. It was filled with commercial argon at 9 atm. pressure. The electrodes E were of paper painted with carbon drawing ink, and a paper guard ring G and potential dividers

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C were used to insure a uniform field. A collecting field of 40 volts per cm. was used throughout the experiments. The collecting volume of the chamber, indicated by the dotted lines, was 550 c.c. Ionization currents were measured with an FP-54 electrometer valve and a modified Barth balanced circuit(3). For the purpose of Table I an arbitrary unit of current of about 3×10^{-15} amp. is employed, and on this basis the natural effect of the ionization chamber (including the grid current of the valve, of the order of 10^{-15} amp.) was $1{\cdot}60 \pm 0{\cdot}05$ units of current. The fluctuation of the natural effect gives the probable error of the readings in Table I.

3. The ionium source

The ionium source previously used by Chadwick and Russell(1) was available for the present experiments. It was a mixture of ionium and thorium and its previous history is given in the literature(4). The amount of radium grown in 1·5 g. of the mixture of ionium plus thorium oxides was measured by the comparison of the γ-ray activity with an International Radium Standard. It was found to be $(2{\cdot}1 \pm 0{\cdot}1) \times 10^{-2}$ mg. Ra and grew from the ionium in 27 years, the time elapsed since the purification previously made by Chadwick and Russell. If the most recent determination of the half-period of ionium(5), $T = 8{\cdot}2 \times 10^4$ years, is used, the percentage of ionium in the mixture is calculated to be $(7{\cdot}8 \pm 0{\cdot}7)$ %. This corresponds to 1·3 mc. of ionium per g. of the ionium-plus-thorium source and is 50 % less than previous estimates(4). The growth of γ-ray activity in the source after removal of all elements except those of atomic number 90 (ionium, thorium and radiothorium) has been followed for a period of two months. The calculation of the percentage composition of the source from these measurements gives $(7{\cdot}0 \pm 0{\cdot}6)$ % ionium, which agrees with the above result within the experimental error. Allowance has been made for the reduction of the radiothorium content of the source below equilibrium value; mesothorium 1, the effective parent of radiothorium, was removed during chemical purifications carried out at intervals over a period of fourteen months.

Control experiments were made with a thorium source which contained no ionium. When chemically separated from its decay products, 1 g. of the thorium-plus-radiothorium had no measurable γ-ray activity. This experiment proved that the γ-radiation from the ionium-plus-thorium source must be attributed to the disintegration of ionium.

4. Experimental results

Preliminary experiments using a pressure ionization chamber of 250 c.c. volume, containing argon at 50 atm., showed no detectable γ-ray activity from the ionium for absorbing thicknesses of lead greater than 3 mm. The growth of γ-ray activity from the formation of radium and thorium products could easily be measured. The smallest detectable amount of radium (in equilibrium with its products) was 2×10^{-6} mc.

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After a second purification, 0·8 g. of the source was used for absorption measurements with the experimental arrangement of Fig. 1. The ionization currents for a series of absorbers of varying atomic number are given in Table I. The measurements have been corrected for the growth of activity due to the formation of radium and thorium products during the experiments. The readings of Table I are plotted semi-logarithmically in Fig. 2.

Table I

Absorber	g./cm.²	Ionization current	Absorber	g./cm.²	Ionization current
None	0	3·45	None	0	3·45
Pb	0·039	2·97	Cd	0·261	1·25
Pb	0·427	0·81	Cd	0·542	0·62
Pb	0·879	0·22	Cd	0·854	0·38
W	0·292	1·62	Cu	0·532	2·06
W	0·605	0·82	Cu	0·803	1·52
W	0·866	0·52	Cu	1·422	0·90
Ta	0·175	1·10	Cu	2·76	0·35
Ta	0·352	0·61			

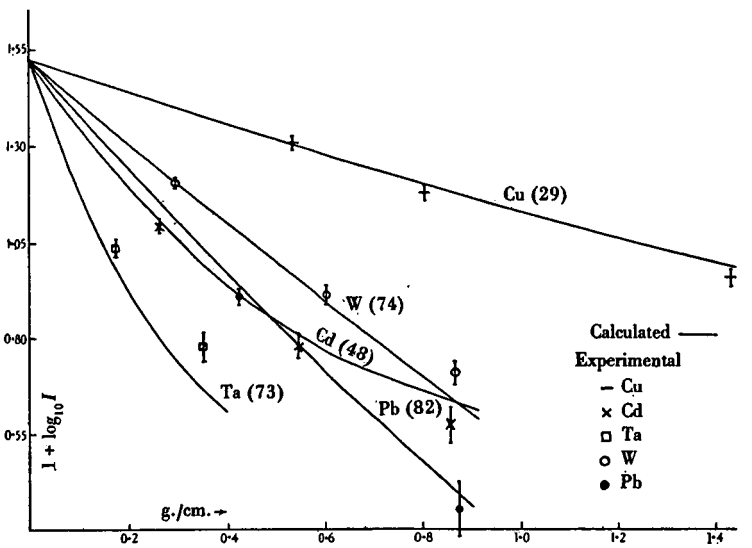


Fig. 2.

5. Discussion of results

The marked difference in the absorption of the radiation by tantalum and by tungsten shows the presence of a γ-ray whose energy lies between the K-absorption energies of the two metals, 67·2 and 69·2 k.e.V. (γ-radiation corresponding to the L discontinuity would be completely absorbed in the aluminium window of the ionization chamber). Since the K-radiations of ionium (thorium)

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and radium have energies of approximately 110 k.e.V., this must be a nuclear γ-ray from the α-particle disintegration of ionium.

A further analysis of the absorption curves, using absorption coefficients as given by S. J. M. Allen (6), indicates a second γ-ray of 190 ± 20 k.e.V., contributing 17 % of the initial intensity.

It need not necessarily follow that only a single harder component is involved, but a more detailed analysis is not considered justifiable, because of the small initial intensity and the necessarily poor geometry of the experimental arrangement. The geometry is not important for the identification of the γ-ray of energy 68 ± 1 k.e.V. by the method of absorption edges.

In Fig. 2 theoretical absorption curves are given, based on the assumption that the above-mentioned two components are present with the stated intensities. The reasonably close agreement with the experimental points provides considerable support for the original conclusions.

The following considerations have been used to make a rough estimate of the number of quanta of each γ-ray emitted per disintegration. Absorption in the source and in the window of the ionization chamber reduces the intensity to 30 % and 50 % for the γ-rays of energy 68 and 190 k.e.V. respectively. This gives 9·5 and 1·2 units of intensity for the unabsorbed radiations. The ionization produced by the γ-ray of energy 2620 k.e.V. from Th C'' has been used for comparison and is approximately equal to 20 units of intensity for 10^{-3} mc. of Th C''. The ionization function of the chamber is assumed to be proportional to $E(\sigma_a + \tau)$, where E is the energy of the γ-ray, σ_a the scattering absorption coefficient and τ the photoelectric absorption coefficient for argon. The ionization function of the chamber is calculated to be 1 : 0·1 : 0·3 for γ-ray energies of 2620, 190 and 68 k.e.V. respectively. When the γ-ray intensities given above are divided by the corresponding value of the ionization function, the γ-radiation from the ionium-plus-thorium source (about 1 mc. ionium) is approximately equal to 1 quantum in 10^3 disintegrations for both the γ-rays, of energy 68 and 190 k.e.V.

Unless these γ-rays suffer almost complete internal conversion, and the results of Chadwick and Russell do not appear to support this hypothesis, then it is obvious that it will be very difficult to obtain direct evidence for the α-particle fine structure which would naturally be associated with the emission of radiation.

Summary

The absorption of the harder γ-rays from ionium has been studied, the first, of energy 68 ± 1 k.e.V., by the method of bracketing, making use of the K absorption discontinuities of tantalum and tungsten; the second, of energy 190 ± 20 k.e.V., by analysis of the absorption curves. The intensity of these γ-rays is estimated to be 1 quantum in 10^{-3} disintegration for each γ-ray.

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