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ART. XXXIX.—*On the Relative Activity of Radium and Thorium, measured by the Gamma-Radiation;* by A. S. EVE.

THE recent work of Boltwood* and of Dadourian† proves that about one-half of the radio-thorium in radio-active minerals is abstracted in the chemical processes of preparing the commercial salts of thorium. This fact was established independently by the two observers, the one measuring the α-activities of the minerals and the salts, the other comparing the activities of their respective emanations. Thus they found per gram of thorium more radio-thorium in thorianite than in thorium nitrate, the ratio being about 2·1 or 2·6 to 1. Boltwood further states that "the specific activity of thorium with its equilibrium quantities of disintegration products is constant."

The present paper deals with the following points:—

I. To determine the ratio of the gamma-activities of radium and thorium when both are in radio-active equilibrium.

II. To ascertain the relative amounts of radio-thorium in thorianite and thorium nitrate respectively, by measurement of the gamma-radiations.

The object of the experiment was not to verify the work of Boltwood and of Dadourian, but to test the γ-radiation method, ascertaining if the results obtained by it were in good agreement both with the α-ray method and with the emanation method. Such was found to be the case.

* This Journal, June, 1906, pp. 409, 415. † Ibid., p. 427.

In a previous paper* I have proved that the γ-rays from radium and from thorium are absorbed at a precisely equal rate during their passage through lead, whilst the γ-rays from uranium are much more readily absorbed. In the same paper, the ratio of the γ-activities of radium and thorium was also stated, but erroneously, inasmuch as thorium nitrate was used for the determination, and we now know that the thorium was therefore not in radio-active equilibrium. Furthermore, it has been shown† that the observable γ-radiation from radium in equilibrium is due solely to radium C. In the case of thorium it is known that the γ-rays are due to thorium C. Therefore, the γ-radiation of thorium C, which is, in due sequence, a disintegration product of radio-thorium, is a measure of the radio-thorium present. We should, therefore, expect the γ-radiation of a thorium mineral or salt to be proportioned to the amount of radio-thorium present. So that the results of γ-ray observations ought to be in agreement with those made by the α-rays or by the emanation method.

In the experiments the gamma-radiation was measured in the usual manner by an electroscope.

The substances compared were as follows:

(1) Radium bromide, equivalent to $\cdot 25^{mg}$ as compared with the sealed standard at the Physics Building, McGill University. This standard consists of $3 \cdot 69^{mg}$ of radium bromide, which Rutherford found gave per gram a heating effect of 110 gram-calories an hour.

(2) Thorianite, Ceylon, 454 grams, containing 11 per cent of uranium and 79 per cent of ThO_2.

(3) Thorium nitrate, prepared by Eimer and Amend, received from them a year ago, which contains 47 per cent of ThO_2.

The activities of these three substances, measured by their γ-radiation, were respectively proportioned to

(1) 18·5
(2) 8·34
(3) 1·38

These are the means of several observations under varied conditions, and are the actual divisions per minute observed with the electroscope.

Specific Activities.

(1) The activity of the radium bromide, under the conditions of the experiment, was 18·5/·25 per mg. or 74,000 per gram.

* Phil. Mag., April, 1906. † This Journal, July, 1906.

(2) The specific activity of the thorium in the thorianite requires some consideration. Of the 454 grams of thorianite employed, 360 grams consist of ThO_2, and 50 grams of uranium. The γ-radiation of the uranium itself can be ignored, as it could not produce a sufficient effect through the thickness of lead employed. But with the uranium there will be an amount of radium present in the proportion determined by Rutherford and Boltwood. Thus the 50 grams of uranium are associated with $50 \times 3{\cdot}8 \times 10^{-7}$ grams of radium, or the equivalent of $3{\cdot}3 \times 10^{-5}$ grams of radium bromide. But $\cdot 25^{mg}$ of radium bromide had an activity of 18·5 as measured by the electroscope, and, therefore, the radium in the thorianite would produce a deflection of $18{\cdot}5/{\cdot}25 \times 3{\cdot}3 \times 10^{-2}$ or 2·47 divisions a minute. Deducting this from the total activity of the thorianite, namely, from 8·34, we have an activity of 5·87 due to the thorium and all its products, so that the specific activity is 5·87/360 or ·0163.

(3) An analysis of the thorium nitrate showed that 47 per cent of ThO_2 was present, so that 213 grams of ThO_2 had an activity of 1·38, or a specific activity of ·0065.

The specific activities here given are dependent on the electroscope used, on the thickness of the lead employed and on the distance of the substances from the electroscope. But the *ratios* of the specific activities is independent of the conditions of the experiments, except for a small correction due to the fact that the substances cannot be concentrated at a point.

The following results are, therefore, deduced:—

(a) The thorium and its products in the thorianite is more active than the thorium and its products in the thorium nitrate in the ratio of ·0163 to ·0065, or of 2·5 to 1. This is in very good agreement with Boltwood's results.

(b) Radium bromide in radio-active equilibrium is more active than an equal mass of ThO_2 in radio-active equilibrium in the ratio of 74,000 to ·0163 or of $4{\cdot}5 \times 10^6$ to 1.

Therefore, *radium* is $6{\cdot}9 \times 10^6$ times as active as *thorium* when both are in radio-active equilibrium, when the activity is measured by the γ-rays.

In a previous paper the writer suggested that a kilogram of commercial thorium nitrate might be a convenient standard for γ-ray measurement. This suggestion was not a good one, because recent work has shown that radio-thorium would be continually increasing in such a standard, so that the activity would vary at a rate at present unknown. The only feasible

plan for providing standards seems to be by comparison with a sealed standard of radium bromide of known weight and purity.

Results.

(1) Radium bromide is $4{\cdot}5 \times 10^6$ times as active as ThO_2, or *radium* is $6{\cdot}9 \times 10^6$ times as active as *thorium*, measured by the γ-rays, when both are in radio-active equilibrium.

(2) The ratio of the quantity of radio-thorium per gram of thorium present in thorianite and in thorium nitrate has been measured by Boltwood, using the α-ray method; by Dadourian, using the emanation method; and, subsequently, by the writer, using the γ-ray method. The results obtained by these different methods are in good agreement.

With much pleasure I acknowledge the helpful advice of Professor Rutherford.

McGill University, Oct. 1906.