LETTERS TO THE EDITOR.

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The Complex Nature of Thorium.

WITH regard to several letters on thorium and its complex nature that appeared in NATURE of March 24 and 31, April 7 and 14, and in which my name is mentioned, I take the liberty of adding a few remarks, having had ten years' experience in working with thorium.

In 1897, at a meeting of the British Association in Toronto (Canada), I read a paper in which I pointed out that spectrum evidence proves the complex nature of thorium.

In 1898 (Chem. Soc. Trans., p. 953) I isolated from some thorium fractions an earth with an atomic weight of 225.8 (tetrad). Knowing the difficulties of the separation of rare earths (I have been engaged in this kind of work since 1878), and not wishing to publish a premature conclusion, I did not declare this to be a novel constituent of thorium, but said that foreign earths were present, in spite of the fact that the reaction used ought to have separated them.

In 1901 I published another short paper (*Proc. Chem. Soc.*, March 21, 1901, pp. 67-68), in which I said that "my experiments may be regarded as proving the complex nature of thorium." Thorium was split up into Th α and Th β . With Th β I obtained so low an atomic weight as R iv =220. The fractions Th α gave by the analysis of the oxalate, though it was prepared by pouring the thorium salt solution into an excess of oxalic acid, in order to avoid the formation of a basic salt, the high atomic weight R iv =236.3. But I stated expressly, and I feel obliged to repeat it, that these fractions show a great tendency to form basic salts. Assuming these to be normal, a higher atomic weight than the true one is obtained. This is true especially in regard to the oxalate.

The splitting up of thorium into Th α and Th β was, of course, not so sensational an event as the announcement from America of the splitting up of thorium into "carolinium" and "berzelium."

BOHUSLAV BRAUNER.

Bohemian University, Prague, April 18.

Radio-activity and the Law of Conservation of Mass.

MR. SODDY in the Wilde lecture on the "Evolution of Matter as Revealed by the Radio-active Elements" (*Proc. Manchester Phil. Soc.*, vol. xlviii., part ii., p. 29) gives two methods of deducing the average life of a radium atom. The results become concordant if we assume that the complete disintegration of an atom of radium involves the emission of four α particles. Now the atomic mass of radium is 225, and that of an α particle about 2; the question therefore arises as to what has become of the rest of the mass.

There appear to be three possible answers to this question. In the first place Mr. Soddy's estimate may be wrong by a factor of ten, although it is hardly likely that the data are uncertain to this extent; secondly, the various stages of the disintegration may involve the liberation of non-radio-active by-products which would necessarily be incapable of detection by the methods of investigation employed; and, finally, there may be a decrease in the total mass of the system owing to the decrease in the velocities of some of the constituent electrons.

A priori the second hypothesis appears to have the balance of probability in its favour, as it agrees best with our present ideas; but I think the third solution should not be dismissed too hastily. In discussing the matter recently with Mr. G. A. Schott, I found that he also had been led to consider the tenability of this view in connection with some theoretical work on the structure of the atom which will probably soon be published.

O. W. RICHARDSON.

Trinity College, Cambridge, April 19.

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The Atomic Weight of Radium.

IN the *Philosophical Magazine* for April, 1903, Runge and Precht work out the atomic weight of radium from its spectrum to be 258, instead of the 225 found by Madame Curie. I should like to point out that the spectrum data of radium support the value given by Madame Curie, if handled according to Section v. of "The Cause of the Structure of Spectra" (*Phil. Mag.*, September, 1901). There is an important question of principle involved in the distinction between the two methods of using the spectrum of an element for determining its place in the periodic classification.

The method adopted by Runge and Precht is founded on a slight alteration of the approximate empirical law discovered by Rydberg, that, when similar elements have corresponding pairs or triplets of lines in their spectra, the difference of the frequencies of vibration of the two lines in a pair belonging to any one element is proportional to the square of its atomic weight. Runge and Precht alter this law by substituting the words "some power of its atomic weight" for "the square of its atomic weight." Thus in the alkaline earth family they give the power as $1/0.5997$. The frequency differences of corresponding pairs of lines in Mg, Ca, Sr and Ba, namely, 91.7, 223, 801 and 1691 being denoted by x , the logarithms of the atomic weights M of these elements are given by the formula $\log M = 0.2005 + 0.5997 \log x$. As x for radium is 4858.5, the value 258 is found by Runge and Precht for the atomic weight of radium. But the frequency differences are connected with one another by numerical relations, and not directly by their atomic weights.

The clearest instance of this purely numerical relationship is shown by the spectra of Zn, Cd, and Hg. A characteristic set of corresponding frequency differences for these elements is 386.4 for Zn, 1159.4 for Cd, and 4633.3 for Hg. The number for Zn multiplied by 3 gives 1159.2, which is indistinguishable from the value for Cd, and 12 times the number for Zn gives 4636.8, which is within 1 part in 1000 of the value for Hg.

In the paper mentioned I have shown now this numerical series, 1, 3, 12, appears elsewhere in the frequency differences for other families of elements, with a fourth member, namely, 28. Now these numbers are the first four terms of the series the general term of which is $1 - 3n/2 + 7n^2/2$. This series, and not atomic weights, controls the relations between the frequency differences for the spectra of allied elements.

Perhaps the most striking evidence in support of this assertion is afforded by some characteristic frequency differences discovered by Runge and Paschen in the complicated spectra of O, S, and Se. These are for O 3.7 and 2.08, for S 18.15 and 11.13, and for Se 103.7 and 44.07. Of these six numbers four are the first four terms of the series the general term of which is $3.7(1 - 3n/2 + 7n^2/2)$, namely, 3.7, 11.1, 44.4, and 103.6. The numerical law applies, then, to the non-metals as well as to the metals. The distinction between a purely numerical and an atomic weight relation between the frequency differences of allied spectra is fundamental, the one implying a kinematical, the other a dynamical, origin for the structure of spectra.

As to the bearing of these considerations on the determination of the atomic weight of radium from its spectrum we can represent the differences given above for the alkaline earth elements by the formula $63.8(1, 3, 12, 26) + 31.6$, in which 26 for Ba takes the place of 28 in the standard series. There are other instances in which a serial number like 12 or 28 is reduced by 2 or 4, a phenomenon probably of kinematic origin. For the next three elements of this family with higher atomic weights than Ba, the frequency differences corresponding to those just given should be the values of $63.8(1 - 3n/2 + 7n^2/2) + 31.6$, given when $n=4, 5$ and 6. The coefficients of 63.8 are 51, 81 and 118. Now the 4858.5 of Runge and Precht for radium is $63.8 \times 75.7 + 31.6$. Thus the 75.7 of radium corresponds to the 81 of the regular series in the same way that the 26 of Ba does to the 28 of the regular series. So the numerical law for the frequency differences places radium two main rows lower than Ba in the table of elements, and gives to it, therefore, an atomic weight exceeding that of Ba, namely,