## LETTERS TO THE EDITOR.

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### Radium and its Disintegration Products.

IN NATURE of December 6, 1906, Mr. H. S. Allen has suggested that the difficulty encountered in introducing actinium with its four $\alpha$-ray products between uranium and radium can be removed by assuming that the $\alpha$ particle is one-half of the helium atom, and he has applied this suggestion in a table showing six $\alpha$-ray changes between uranium and radium. There would appear to be two serious and insurmountable objections to this view, however, viz., (1) the continuation of the same line of reasoning would lead to the assumption of no less than seven $\alpha$-ray changes between radium and its final disintegration product, lead, while but four are known; and (2) the activity of the actinium in equilibrium with radium in minerals is entirely too low to permit any such conclusion.

That lead is the final disintegration product of uranium is, I believe, conclusively shown by the fact that in unaltered *primary* minerals from the same locality the amount of lead is proportional to the amount of uranium in the mineral, and that in unaltered primary minerals from different localities the amount of lead relative to uranium is greatest in the minerals from the locality which, on the basis of geological data, is the oldest.

In the case of a non-emanating, radio-active mineral containing no thorium, in which there is reason for assuming that the elements of the uranium-radium series have reached a state of equilibrium, the activity of the mineral in extremely thin films measured in an electroscope with a large ionisation chamber is about 5·3 times as great as the activity of the uranium present in the mineral. The activity of the radium itself is about 0·52 of the activity of the uranium, and the activity of the radium products of rapid change together about 2·4 times that of the uranium. The activity of the radium F (polonium) is probably about 0·55 uranium, and is certainly not less than 0·5. The combined activity of the uranium, the radium, and the radium products is therefore about 4·5 times the activity of the uranium alone. This leaves an activity of only 0·8 that of the uranium which can be attributed to the activity of the four $\alpha$-ray products of actinium. It was the knowledge of the approximate value of this factor which led Prof. Rutherford and the writer to conclude (*Amer. Jour. Sci.*, xx., 56, 1905) that actinium was not a direct product of uranium in the same sense as is radium.

The ranges of the four $\alpha$ particles expelled by the actinium products have been determined by Hahn, and the average range of the four is 5·6 cm. The range of the $\alpha$ particle from radium itself is 3·5 cm. according to Bragg and Kleeman. If the particles are similar we would expect that the average particle from the actinium products would produce about 1·6 times the ionisation of the particle from radium. Since the activity of radium itself is 0·52 times that of the uranium in the mineral, the activity of the four actinium products might be expected to be $0{\cdot}52 \times 1{\cdot}6 \times 4 = 3{\cdot}32$ uranium. The number actually found, as has been stated above, is only 0·8 uranium, or one-fourth of this number.

It will be noted in the above that the activity of the uranium is about twice that of the radium present, which is in good agreement with the conclusion of Moore and Schlundt that there are two $\alpha$-ray changes in uranium, if it is assumed that the average range of the two uranium particles is about 3·5 cm.

Although speculations of this sort are of doubtful value, the following suggestion may be sufficiently interesting to warrant its intrusion:—if the two changes in uranium and the five changes in radium are each assumed to take place with the expulsion of *four* $\alpha$ particles, and the four changes in actinium with the expulsion of only *one* $\alpha$ particle each, the conditions required by the relative activities of the various substances would appear to be fulfilled, and if, moreover, the mass of each $\alpha$ particle be taken as 1, then the indicated atomic weights of the successive elements are in fairly good agreement with the accepted values. We have then uranium = 238·5, actinium = 230·5, radium = 226·5, and radium F (lead) = 206·5. In making this suggestion I fully appreciate that I am taking liberties with the accepted value of $e/m$ for the $\alpha$ particle.

It is of further interest to note that the activity of pure radium, calculated from the relative activity of the uranium and radium in minerals and the relative quantities present (Rutherford and Boltwood, *Amer. Jour. Sci.*, xxii., 1), is indicated as about $1{\cdot}4 \times 10^6$ times that of uranium, and the activity of pure radium bromide containing the equilibrium amounts of emanation and products of rapid change as about $3 \times 10^6$ times uranium.

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### The $\alpha$ Rays.

THE $\alpha$ rays from radium appear to start life without electric charge, and subsequently become charged owing to collisions with the gas molecules they strike in their path. It seems, therefore, worth while inquiring what their behaviour would be if they were liable to become discharged again at a later collision, and to go on repeating this cycle during the ionising portion of their path. Very possibly the $\alpha$ particle is capable of losing more than one electron, in which case it would seem certain that it will have a greater charge at some portions of its path than at others. Looked at in this way the problem is a statistical one of considerable complexity, but my point of view will be sufficiently well illustrated by considering the average $\alpha$ particle to behave as if it had the following constitution. For a distance $x$ of its path it possesses an electric charge $e$. This is succeeded by a distance $x'$, during which its electric charge is $e'$. This is followed by a distance $x$ with charge $e$, then a distance $x'$ with charge $e'$, and so on, repeating indefinitely. Let the particle have a mass $m$ and initial velocity $v_0$, then, confining our attention to a portion of the path so small that $v_0$ is not appreciably diminished by the collisions which occur, it is easy to show that the quantity measured by the electrostatic deflection as $mv_0^2/e$ would really be $\frac{mv_0^2(x+x')}{ex+e'x'}$, whilst the quantity measured by the electromagnetic deflection as $mv_0/e$ would be $\frac{mv_0(x+x')}{ex+e'x'}$. Thus the measurements would give $v_0$ correctly, but the quantity denoted by $e/m$ would be $\frac{ex+e'x'}{m(x+x')}$. It is evident that the apparent value of $e/m$ would be independent of the pressure at which the measurements were made, since change of pressure changes both $x$ and $x'$ in the same ratio.

It is interesting to see what would happen if the $\alpha$ particle were *uncharged* during one series of portions of its path, and carried the ordinary electrolytic unit of charge $e$ during the alternating portions. If the alternate stretches were equal, this is what would be obtained if it were an even chance whether the $\alpha$ particle escaped with or without a charge after each encounter. In this case we should have $x = x'$ and $e' = 0$, and the measured $e/m$ would really be $e/2m$. On this view Rutherford's measurements would indicate that the $\alpha$ particles are hydrogen atoms with the normal charge instead of helium atoms with twice that charge.

It may well be that it is a matter of chance whether the atom struck or the $\alpha$ particle retains the positive charge after an ionising encounter, but I do not wish to imply that this warrants the conclusion that the $\alpha$ particle is a hydrogen atom. If we accept this conclusion we find ourselves face to face with serious difficulty in finding a place for helium in the story of radio-active change; but even if the $\alpha$ particle turns out to be a helium atom it is possible that its charge might vary periodically in something like the manner indicated. In this case the average charge would have to be twice the electrolytic unit.

This kind of view has the advantage of affording a