On some α-Ray tracks. By C. T. R. Wilson, F.R.S.

(Plates III, IV.)

[*Read* 27 November 1922.]

I have recently been applying the cloud method mainly to the study of X-rays and β-rays. A number of stereoscopic pictures of α-ray tracks were however taken to test the working of the apparatus. Some of these are of interest in themselves and as illustrating points regarding the applications of the method and the interpretation of such photographs.

The pictures here reproduced (on four times the scale of the original objects) were all obtained by spreading a small quantity of Thorium oxide along a narrow strip across the middle of the floor of the cloud-chamber* (which was about 18 cms. in diameter and 3 cms. in height) and covering the oxide with black paper. Thorium emanation is continually diffusing through the paper into the air of the cloud-chamber. From time to time an emanation atom ejects an α-particle and within a small fraction of a second an α-particle is in turn ejected by the resulting Thorium-A atom. A potential difference was maintained between the roof and floor of the cloud-chamber, the roof being negative so that free positive ions travelled upwards, negative downwards. The clouds condensed on the ions as a result of sudden expansion of the air were photographed through the side of the cloud-chamber.

In the left half of Fig. 1, Plate III are visible two inclined diffuse cloud tracks, *b* and *b′*. An α-particle had passed through the air before the expansion occurred and had left a trail of free positive and negative ions; these have been separated by the electric field before being rendered immobile by condensed water. The α-particle had traversed the whole height of the cloud chamber along a path *aa* (whether from roof to floor or floor to roof it is impossible to say); the vertical displacement of the ions (positive upwards, negative downwards) has exceeded half the height of the cloud-chamber. The potential difference maintained between the roof and floor amounted in this case to 100 volts; from the amount of the vertical separation of the tracks, it follows that the α-particle traversed the air about $\frac{1}{30}$ of a second before the expansion.

The other events of which the picture gives a record occurred after the expansion. Near the extreme right of the picture a thorium emanation atom at *d* has ejected an α-particle along *de* downwards and away from the camera, and the ions liberated, including

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* *Roy. Soc. Proc.* A, 87, p. 277, 1912.

the Th A atom, have been at once fixed by condensation of water so that a sharply defined cloud track is formed. (The track goes out of focus as it recedes from the camera and ultimately passes out of the illuminated region.) The Th A atom in the head of this cloud track has within a small fraction of a second ejected an α-particle in a nearly horizontal direction along df. Over the greater part of the length of its path condensation has at once occurred giving a sharply defined and straight cloud track. But in the immediate neighbourhood of the lower end of the diffuse cloud b, already condensed on the positive ions of the older track described above, the new α-particle finds the air robbed of a considerable portion of its water vapour; in consequence no condensation here takes place on the ions liberated by it until they have been carried by the electric field into a region where the necessary supersaturation still exists. In the present case the negative ions moving down under the action of the field have fairly soon reached a region where the water vapour is still sufficiently supersaturated to condense upon them; the V-shaped diversion in the otherwise straight track is thus easily explained. The positive ions have been carried further into the old cloud by the action of the field and have thus left no track, except for a short distance above the two upper ends of the V.

Again, ions formed along the initial portion of the α-ray from Th A (as well as by the recoil atom) were liberated within or very near the cloud which had already condensed along the track of the original emanation α-particle and of the recoiling Th A atom. Condensation on these ions, positive or negative, could thus only take place when they had been carried sufficiently far up or down to enter regions in which the critical supersaturation was still exceeded. The initial portion of the cloud track actually left by the α-particle from the Th A atom is therefore pincer-shaped, and the head of the original α-ray track from the emanation atom lies midway between the jaws of the pincers.

The sharply defined portions of the α-ray track from the Th A atom in Fig. 1 show here and there little projections—the tracks of slow-speed β-rays. Photographs showing such rays originating from α-ray tracks in hydrogen were obtained by Bumstead*; they were called by him fast δ-rays.

A good example of the perfectly straight beaded track of a very fast β-particle is visible towards the right of the picture.

On the other hand the large deviations from straightness which characterise the last few centimetres of the path of a β-particle, when its velocity has been largely reduced by encounters, are well shown in the threadlike track visible in Fig. 2, Plate IV.

Fig. 2, Plate IV shows the initial portions of two α-ray tracks, g and g', each of which starts from an enlarged head—the track of

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* *Physical Review*, VIII, p. 715, 1916.

the recoil atom. The potential difference between the roof and floor was again 100 volts. The short β-ray tracks (Bumstead's δ-ray tracks) radiating from the path of the α-particle are well shown. A number of pictures showing similar features have been obtained. The maximum range of the δ-ray tracks in air at $\frac{2}{3}$ of normal density is between ·4 and ·5 mm. This range greatly exceeds that of the β-rays excited in air by the K-radiation of aluminium and amounts to about one-fifth of that of the longest β-rays excited by copper K-radiations. (The copper and aluminium ranges were obtained also by the cloud method in the course of experiments which will be described elsewhere.) If we assume the range to vary as the cube of the velocity of the β-particle, we find for the δ-rays of maximum range a velocity of about $3{\cdot}5 \times 10^9$ cms. per second—about twice that of the α-particle. We should expect a β-particle which had been expelled from among the relatively slowly moving electrons of the *outer* level of an atom, with a velocity comparable with twice that of the α-particle, to have a large forward component in its velocity. There is however no indication of a preponderating forward component in the pictures; the β-particles generally appear to be emitted nearly at right angles to the α-ray tracks. Accordingly it seems probable that some at least come from the K levels of the atoms.

In none of the photographs do any δ-rays appear on the last two centimetres of the α-ray tracks. This is well illustrated by the stereoscopic picture reproduced in Fig. 3, Plate IV. The potential difference between the roof and floor of the cloud chamber was 20 volts. Here are seen side by side the initial portion of one α-ray track, h, and the final portion of another, i. The initial portion of a third track, k, is also shown crossing the lower part of the picture from left to right.

If we suppose that the range of the δ-rays is proportional to the cube of their velocity like that of the α-ray and that the velocity of the δ-particle is proportional to the velocity of the α-particle which ejects it, then the maximum range of the δ-particle (which is about ·5 mm. at 5 cms. from the end of the α-ray) will only be about 0·1 mm. at 1 cm. from the end. Now a sharply defined α-ray track has generally a radius of about this magnitude, so that near the end of the α-ray track the δ-ray would not project beyond the general cloud track.

It is unlikely however that the distribution of the δ-rays is to be wholly explained in this way. It may be connected with the fact that the velocity of the α-particle near the middle of its course passes through values which on Bohr's theory are comparable with the velocities of the electrons in the K orbits of Oxygen and Nitrogen.

If electrons are expelled from the K level of some of the atoms traversed by the α-particles, we should expect the corresponding characteristic X-radiations to result from the falling in of outer electrons into the vacancies thus created. In Fig. 2 there are in fact visible, at radial distances of 0·5 to 1·5 mm. from the early portion of the α-ray track, minute globular cloudlets—the tracks probably of very short-range β-rays ejected from atoms of the gas by K-radiations which originate in the α-ray track.

Kapitza has found* that the loss of energy of an α-particle per ion liberated is greater in the first part of its path than in the last few centimetres. He suggests that this excess may be due to a certain proportion of the electrons liberated coming from the K level of the atoms. The present experiments tend to confirm that view; they indicate that some of the missing energy may escape as X-rays which are absorbed outside the track.

A much more detailed study of the range and distribution of the δ-rays along a large number of α-ray tracks is obviously required.

The separated positive and negative α-ray cloud tracks of Fig. 1 and similar pictures are sufficiently nearly resolvable into their separate drops to suggest that it may be possible to apply the cloud method to the direct determination of the ionisation along the path of an α-ray or even of a recoil atom. Some of the pictures which have been obtained show in a striking way the much greater density of the ionisation in the recoil tracks.

Another application suggested by some of the photographs is the measurement of the mobilities of the ions and in particular the separation of ions of different mobilities. This is a problem of considerable interest in view of recent work by J. J. Nolan† and others. Some multiple diffuse cloud tracks, e.g. the quadruple track which appears in the background of Fig. 3, are most naturally interpreted as indicating the existence of ions of different mobilities. It is possible, however, that under certain conditions some of the ions escape immediate capture at the moment of expansion and so lose their chance of finding the necessary supersaturation of water vapour till they have been carried by the electric field beyond the influence of the first formed drops.

There is one ion of which it is of especial interest to observe the displacement—i.e. the Th A or similar atom left behind by the expulsion of an α-particle from an emanation atom. The point at which it takes its origin by the expulsion of an α-ray from the emanation atom as well as the point where its life comes to an end by the expulsion of a second α-particle are both marked in a cloud track picture. If the first of these events occurs before the ions are fixed by condensation of water, the second after, we can compare the displacement of the Th A atom with that of the other ions,

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* *Roy. Soc. Proc.* A, 102, p. 48, 1922.

† *Proc. Roy. Irish Acad.* 36, A, p. 81, 1922.

4 x 5½

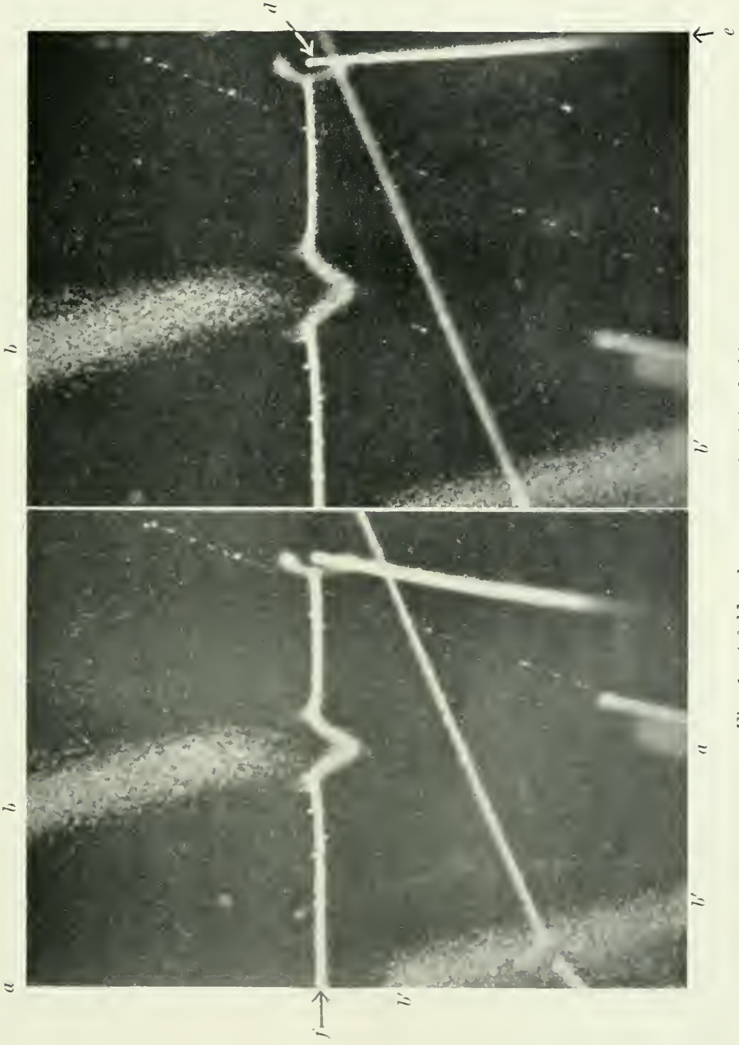

Fig. 1. 4-fold enlargement of original objects

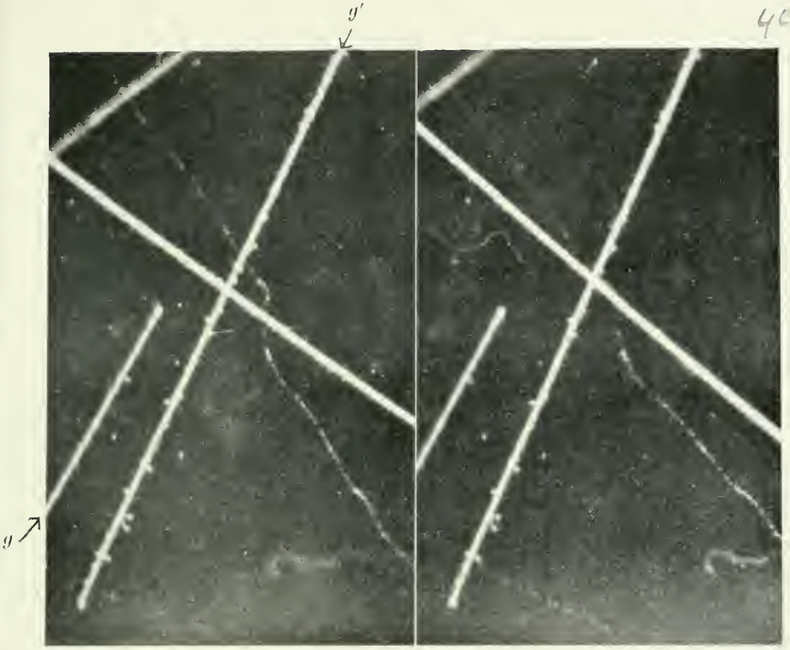

Fig. 2. 4-fold enlargement of original objects

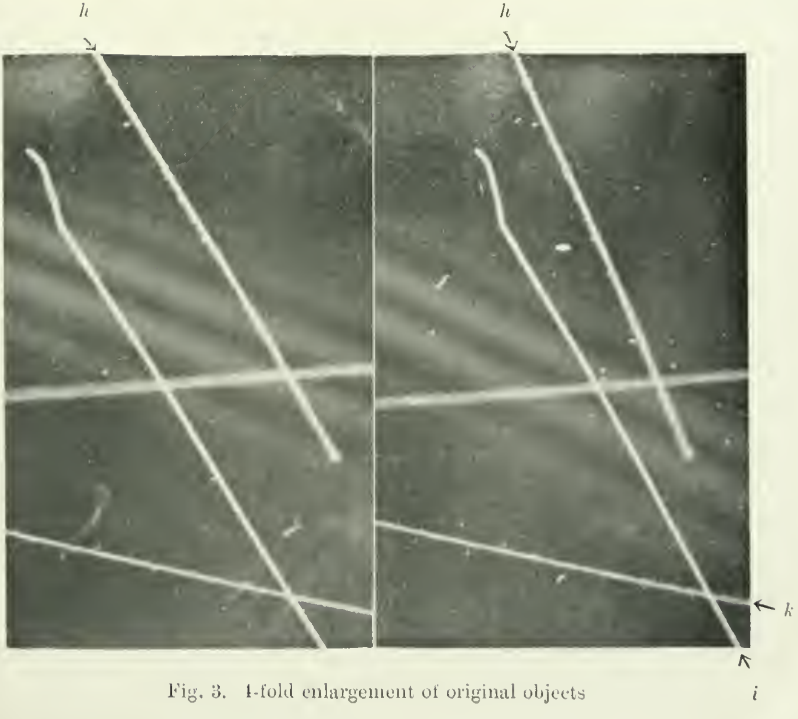

Fig. 3. 4-fold enlargement of original objects