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On a Diffuse Reflection of the α-Particles

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FAC-SIMILÉ NUMÉRIQUE

LE TEXTE

Un an après sa première étude de la diffusion des particules α (*Proc. R. Soc. A* 81, 1908), Hans Geiger reprend la question avec Ernest Marsden, étudiant de vingt ans que Rutherford vient de lui adjoindre. Ils cherchent si des particules α peuvent être renvoyées du côté même où elles frappent une plaque, comme on l'observait pour les particules β. Un écran de sulfure de zinc, abrité de la source par une plaque de plomb, ne reçoit que les particules renvoyées par un réflecteur ; on les compte au microscope, une à une.

Le résultat est net : une petite fraction des particules revient en arrière, d'autant plus que le métal est lourd (tableau de la p. 497). L'effet croît avec l'épaisseur d'or puis sature (fig. 2) : c'est un effet de volume, produit dans une couche très mince. Enfin, avec une source de radium C de flux connu, environ une particule incidente sur 8000 est réfléchie. Dévier ainsi de plus de 90°, dans 6×10^{-5} cm d'or, une particule aussi rapide et aussi lourde demanderait un champ magnétique de 10^9 unités : c'est ce résultat, que Rutherford comparera plus tard à un obus de 15 pouces rebondissant sur une feuille de papier de soie, qui le conduira en 1911 au modèle nucléaire de l'atome.

CETTE ÉDITION

Les six pages des *Proceedings* sont recomposées ligne à ligne, dans le caractère et le format de la note de Geiger de 1908 : chaque ligne est posée à la hauteur relevée sur la numérisation de la Royal Society, chaque page étant d'abord ramenée au même cadre. Les figures 1 à 3 et le tableau sont redessinés en vectoriel d'après l'imprimé (fig. 2 : quadrillage régularisé, courbe suivant le tracé du graveur). Comme dans un tirage à part, les pages 495 et 500 ne portent que cet article (fin et début des articles voisins omis). L'orthographe et la ponctuation de 1909 sont conservées, y compris « the number of scintillations … are given » (p. 497).

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On a Diffuse Reflection of the α-Particles.

By H. Geiger, Ph.D., John Harling Fellow, and E. Marsden, Hatfield Scholar, University of Manchester.

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When β-particles fall on a plate, a strong radiation emerges from the same side of the plate as that on which the β-particles fall. This radiation is regarded by many observers as a secondary radiation, but more recent experiments seem to show that it consists mainly of primary β-particles, which have been scattered inside the material to such an extent that they emerge again at the same side of the plate.* For α-particles a similar effect has not previously been observed, and is perhaps not to be expected on account of the relatively small scattering which α-particles suffer in penetrating matter.†

In the following experiments, however, conclusive evidence was found of the existence of a diffuse reflection of the α-particles. A small fraction of the α-particles falling upon a metal plate have their directions changed to such an extent that they emerge again at the side of incidence. To form an idea of the way in which this effect takes place, the following three points were investigated :—

(I) The relative amount of reflection from different metals.

(II) The relative amount of reflection from a metal of varying thickness.

(III) The fraction of the incident α-particles which are reflected.

* See Schmidt, 'Jahrbuch der Radioaktivität und Electronik,' vol. 5, p. 471, 1908.

† Rutherford, 'Phil. Mag.,' vol. 12, p. 143, 1906 ; H. Geiger, 'Roy. Soc. Proc.,' A, vol. 81, p. 174, 1908.

For the observation of the reflected particles the scintillation method was used in all experiments. With regard to the details of the method we refer to the papers of Regener* and of Rutherford and Geiger.†

On account of the fact that the amount of reflection is very small, it was necessary to use a very intense source of α-rays. A tube was employed similar to that which has been proved to be a suitable source in the scattering experiments of one of us.‡ This source consisted of a glass tube AB (fig. 1), drawn down conically and filled with radium emanation, the end B of the tube being closed airtight by means of a mica window. The thickness of the mica was equivalent to about 1 cm. of air, so that the α-particles could easily pass through it.

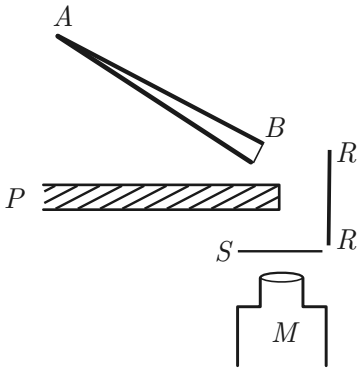


FIG. 1.

Since it is of importance that the gas pressure inside this tube should be as low as possible, the emanation was purified according to the methods developed by Prof. Rutherford.§ The tube contained an amount of emanation equivalent to about 20 milligrammes $RaBr_2$ at a pressure of a few centimetres. The number of α-particles expelled per second through the window was, therefore, very great, and, on account of the small pressure inside the tube, the different ranges of the α-particles from the three products (*i.e.* emanation, RaA, and RaC) were sharply defined.

The zinc sulphide screen S (fig. 1) was fixed behind the lead plate P, in such a position that no α-particles could strike it directly. When a reflector was placed in the position RR at about 1 cm. from the end of the tube, scintillations were at once observed. At the same time the screen brightened up appreciably on account of the reflected β-particles.

By means of a low power microscope, the number of scintillations per minute on a definite square millimetre of the screen was counted for reflectors of different materials. Care was taken that the different reflectors were always placed in exactly the same position.

It is, of course, to be expected that the number of α-particles reflected from the plate would be different in different directions, and would also depend on the angle of incidence. In our arrangement, however, no appreciable difference was found for different angles. This is due to the fact that,

* 'Verh. d. D. Phys. Ges.,' vol. 10, p. 78, 1908.
† 'Roy. Soc. Proc.,' A, vol. 81, p. 141, 1908.
‡ Geiger, 'Roy. Soc. Proc.,' A, vol. 81, p. 174, 1908.
§ 'Phil. Mag.,' August, p. 300, 1908.

owing to the necessity of having the tube very near to the reflector, the angle of incidence varied very much. An investigation of the variation of the effect with the angles of incidence and emergence would necessitate a parallel and very intense source of homogeneous α-rays, which can, however, not easily be realised.

In the following table the number of scintillations observed per minute are given in column 3 ; in column 4 the ratio to the atomic weight is calculated, and it can be seen that this ratio decreases with decreasing atomic weight. The case of lead appears to be an exception which may be due to slight impurities in the lead.

1. Metal.	2. Atomic weight, A.	3. Number of scintillations per minute, Z.	4. A/Z.
Lead	207	62	30
Gold	197	67	34
Platinum.....	195	63	33
Tin	119	34	28
Silver	108	27	25
Copper.....	64	$14 \cdot 5$	23
Iron.....	56	$10 \cdot 2$	$18 \cdot 5$
Aluminium.....	27	$3 \cdot 4$	$12 \cdot 5$

Even in the absence of any reflector about one scintillation per minute was observed. It was easy to show that this was due to a reflection from the air through which the α-particles passed. The numbers on the table are corrected for this effect.

It is interesting to note here that for β-particles the number of reflected particles also decreases with the atomic weight of the reflector.* But while for β-particles the number reflected from gold is only about twice as great as for aluminium, for α-particles the same ratio amounts to about twenty.

(II) We have already pointed out that the diffuse reflection of the α-particles is a consequence of their scattering. According to this point of view, the number of particles reflected must vary with the thickness of the reflecting screen. Since gold can be obtained in very thin and uniform foils, different numbers of these foils were used as reflectors. Each foil was equivalent in stopping power to about $0 \cdot 4$ mm. of air. It was necessary to mount the foils on glass plates, but the number reflected from the glass itself was found to be very small compared even with the number from one gold foil. The curve, fig. 2, gives the result of the measurements.

* McClelland, 'Dublin Trans.,' vol. 9, p. 9, 1906.

The number of scintillations which were due to the reflection from the air is subtracted from each reading. The first point on the curve represents the number of scintillations observed for a glass plate alone as reflector ; the last point (marked 30) gives the number of scintillations when a thick gold plate was used.

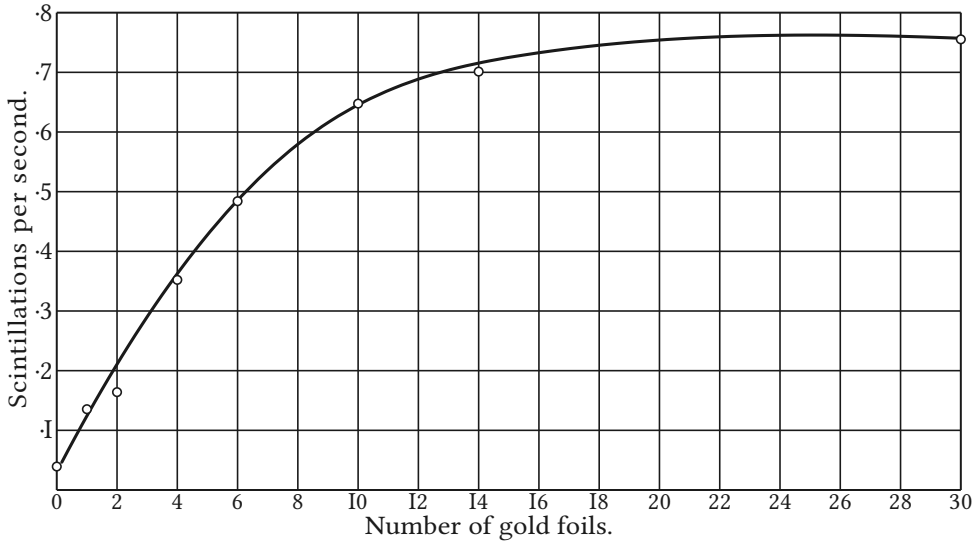


Fig. 2.

The curve is similar to those which have been obtained for the reflection of the β-particles.* It brings out clearly that the reflection is not a surface but a volume effect.

Compared, however, with the thickness of gold which an α-particle can penetrate, the effect is confined to a relatively thin layer. In our experiment, about half of the reflected particles were reflected from a layer equivalent to about 2 mm. of air. If the high velocity and mass of the α-particle be taken into account, it seems surprising that some of the α-particles, as the experiment shows, can be turned within a layer of 6×10^{-5} cm. of gold through an angle of 90°, and even more. To produce a similar effect by a magnetic field, the enormous field of 10^9 absolute units would be required.

(III) In the next experiment, an estimate of the total number of particles reflected was aimed at. For this purpose the emanation tube used in the previous experiments was unsuitable, firstly, on account of the difficulty of correctly ascertaining the number of α-particles emerging from the tube ; and secondly, on account of the different ranges of the α-particles from the

* McClelland, 'Phil. Mag.,' vol. 9, p. 230, 1905 ; 'Ann. d. Phys.,' vol. 18, p. 974, 1905 ; Schmidt, 'Ann. d. Phys.,' vol. 23, p. 671, 1907 ; 'Phys. Zeit.,' vol. 8, p. 737, 1907.

three products : emanation, radium A, and radium C. Consequently, as radiating source, radium C, deposited on a plate of small dimensions, was used. The arrangement, which is sketched in fig. 3, was such that the α-particles from the plate A fell upon the platinum reflector R, of about 1 square centimetre area, at an average angle of 90°. The reflected particles were counted on different points of the screen S.

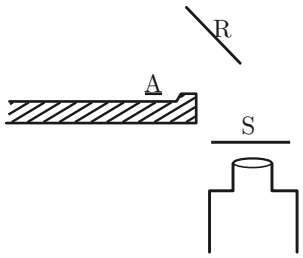


FIG. 3.

No appreciable variation of the number was found with different angles of emergence, the reason of which has already been explained above.

The amount of radium C deposited on the plate was determined by its γ-ray activity. Assuming that $3 \cdot 4 \times 10^{10}$ particles are expelled per second from an amount of RaC equivalent to 1 gramme Ra,* the number of α-particles expelled per second from the active plate was determined. The number falling on the platinum reflector was then easily calculated from its known distance and area. To find the whole number of reflected particles, it was assumed that they were distributed uniformly round a half sphere with the middle of the reflector as centre.

Three different determinations showed that of the incident α-particles about 1 in 8000 was reflected, under the described conditions.

A special experiment conducted at low pressure showed that in the case of grazing incidence the number of particles reflected at a very small angle to the reflector is largely in excess of the number calculated from the above ratio. This tangential scattering is of considerable importance in some experiments ; for instance, if α-particles from a radio-active source are fired along a glass tube of appreciable length the conditions are very favourable for this effect. The number of scintillations counted on a screen sealed to the other end of the tube is made up not only of the particles striking the screen directly, but also of those which have been reflected from the glass walls of the tube.

The correction for the latter effect may be appreciable, and would be still greater in the case of a metal tube. In the counting experiments of Rutherford and Geiger this effect did not influence the final result, the arrangement being such that the reflected particles were prevented from entering the opening of the ionisation vessel by the narrow constriction of a stopcock.

It appears probable that the number of reflected particles depends also upon the velocity of the α-particles falling on the reflector. In our case

* Rutherford and Geiger, 'Roy. Soc. Proc.,' A, vol. 81, p. 162, 1908.

the particles from the radium C had to travel through a little over a centimetre of air before reaching the reflector. The reflected particles had still an appreciable velocity, since, by interposing an aluminium foil of thickness equivalent in stopping power to $\frac{1}{2}$ cm. of air, the number of scintillations counted was not changed. This might be expected from Experiment (II), which showed that the α-particles are reflected from a relatively thin surface layer of the reflector.

We are indebted to Prof. Rutherford for his kind interest and advice throughout this research.