Letters to the Editor.

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Recoil of Electrons from Scattered X-Rays.

IN a recent paper before the Royal Society (as reported in NATURE, July 7, p. 26), C. T. R. Wilson announced that in his cloud expansion pictures of secondary β-rays produced by X-rays shorter than 0·5 Å, tracks of very short range appear. These electrons, he says, "are ejected nearly along the direction of the primary X-rays."

A quantum theory of the scattering of X-rays, devised primarily to account for the change in wave-length which occurs when X-rays are scattered, led me to predict (Bulletin National Research Council, No. 20, pp. 19 and 27, October 1922) that electrons should be ejected from atoms whenever X-rays are scattered. The idea is that a quantum of radiation is scattered in a definite direction by an individual electron. The change in momentum of the radiation, due to its change in direction, results in a recoil of the electron which deflects the ray. The direction of recoil is not far from that of the primary beam, in accord with Wilson's observation on his short tracks.

Corresponding to this momentum acquired by the electron, it has kinetic energy which varies from 0 when the scattered X-ray proceeds forward, to a maximum value $h\nu . 2\alpha/(1+2\alpha)$, when the ray is scattered backward (P. Debye, *Phys. Zeitschr.* 24, 161, Apr. 15, 1923; A. H. Compton, *Phys. Rev.* 21, 486, May 1923). Here $\alpha = \gamma/\lambda$, where $\gamma = h/mc = 0{\cdot}0242$ Å, and λ is the incident wave-length. The ratio of the maximum energy of a photoelectron excited by an X-ray to the maximum energy of such a recoil electron would thus be $(1+2\alpha)/2\alpha$. But Wilson finds the length of the trails proportional to the square of the energy. The track due to the photoelectron should therefore be $(1+2\alpha)^2/4\alpha^2$ times that of the longest recoil electron tracks.

Taking Wilson's datum that a track of 1 cm. corresponds to 21,000 volts, the equation $Ve = hc/\lambda$ indicates that a ray of wave-length 0·5 Å will eject a photoelectron with a path of 1·4 cm. The recoil electron, taking $\alpha = 0{\cdot}0242/0{\cdot}5$, should accordingly have a range of 0·11 mm., which should just be visible. For his harder X-rays, with a wave-length for example of 0·242 Å ($\alpha = 0{\cdot}1$), the recoil tracks on Wilson's photographs should be as long as 1·7 mm. The quantum idea of X-ray scattering thus leads to recoil electrons moving in the right direction and possessing energy which is of the same order of magnitude as that possessed by the electrons responsible for C. T. R. Wilson's very short tracks.

ARTHUR H. COMPTON.

University of Chicago,
August 4.

As Prof. Compton points out, the phenomena relating to the forward directed β-ray tracks of short range, which appear in air exposed to X-rays of short wave-length, are in agreement with his suggestion that scattering of a quantum may be effected by a single electron.

That the phenomena are in general accordance with Compton's theory was pointed out in my paper (which has now appeared in the current number of the Proc. Roy. Soc.); mention of this was made in my summary of the paper, but was omitted in the abbreviated report of that summary which appeared in NATURE of July 7.

It is obvious that further observations on the range and direction of tracks of this type produced by homogeneous radiations may throw light on some very fundamental questions. The data thus far obtained by this method are not sufficient to decide without ambiguity whether a quantum of radiation scattered by an electron is emitted in one direction only or with a continuous wave-front.

C. T. R. WILSON.

Cambridge, August 24.

Long-range Particles from Radium-active Deposit.

WITH reference to the communication of G. Kirsch and H. Pettersson in the issue of NATURE of September 15, p. 394, on the "Sources of long-range H-particles," the results of an examination by the scintillation method of the particles emitted by radium-active deposit, in which we have been engaged for the past six months, are of interest.

It was found that the active deposit, radium B + C, on a brass disc emitted particles with ranges (in air at 15° C. and a pressure of 760 mm. of mercury) of 9·3, 11·1, and 13·2 cm. respectively, as well as particles of which the range was considerably greater than 18 cm., which were not further investigated, as they appeared to be H-particles. The particles of range 9·3 cm. were previously observed by Sir Ernest Rutherford (*Phil. Mag.*, xxxvii., 1919, p. 571).

Although it would not be possible definitely to decide that these particles were α-rays except by their deflexions in electric and magnetic fields, the appearance of the scintillations strongly suggests that they are α-rays. The numbers of these additional particles were relatively very small; for every 10^7 α-rays of range 6·97 cm. emitted by the source, there were present 380, 126, and 65 particles of ranges 9·3, 11·1, and 13·2 cm. respectively, together with about 160 long-range H-particles.

To ensure that these long-range particles were not produced by collisions by the 6·97 cm. α-particles with air molecules, the experiments on the 11·1 and 13·2 cm. particles were repeated, using carbon dioxide in place of air. In this case the equivalent ranges in air were found to be 11·3 and 13·6 cm. respectively, the agreement being considered satisfactory, as the measurements in carbon dioxide were not made with the same precision as in air.

Moreover, these particles could not have been excited in the mica sheets which were used to provide screens of various stopping powers, for the majority of the experiments were carried out with air or carbon dioxide gaps between the source and the mica, sufficiently large to prevent the 6·97 cm. α-rays from reaching the mica.

The particles under consideration appeared to be independent of the metal on which the deposit was formed, as a check determination of the range of one set of particles, emitted from an active deposit on a platinum disc, gave a value of 11·2 cm.

It seems possible, therefore, that the 12, 13, and 10 cm. H-particles which Kirsch and Pettersson considered to arise from the collisions of α-particles from their emanation tubes with atoms of beryllium, magnesium and lithium, respectively, are actually long range α-particles emitted by the active deposit. It is of interest to note that, should the particles of range 13·2 cm. later prove to be α-particles, they will be the longest range α-particles yet discovered.

Further details of our results and experimental