# ON THE MECHANISM OF X-RAY SCATTERING

BY ARTHUR H. COMPTON

DEPARTMENT OF PHYSICS, UNIVERSITY OF CHICAGO

Read before the National Academy April 28, 1925

It is now well known that whereas the usual form of the wave theory is inadequate to account for the alteration of the wave-length of X-rays when scattered, this may be explained simply on the hypothesis that the X-rays consist of quanta, each of which interacts with an individual electron. Strong support of this hypothesis is found in the discovery that there appear electrons each with about the momentum it should have acquired if it had deflected an X-ray quantum. That these electrons are associated with the scattered X-rays is evident from the fact that there exists on the average about one such electron for each quantum of scattered X-rays. Nevertheless the great weight of the evidence from many sources for the wave theory of radiation makes the acceptance of this radiation quantum hypothesis difficult.

It is improbable that the idea of spreading waves of radiant energy can be successfully reconciled with these studies of X-ray scattering without abandoning the principles of the conservation of energy and momentum. However, by making this bold step, Bohr, Kramers and Slater have apparently been able to incorporate them within the general scheme of the wave theory.

While discussing this matter in November 1923, Professor Swann called the attention of Professor Bohr and myself to the fact that a crucial test between the two theories could be made if it were possible to detect simultaneously a scattered quantum and the recoiling electron associated with it. For on any spreading wave theory, including that of Bohr, Kramers and Slater, there should be no correlation between the direction of ejection of the recoil electron and that of the effect of the scattered quantum. On the quantum view, however, if the recoiling electron is ejected at an angle $\theta$ with the incident X-ray beam, the scattered quantum should appear at an angle $\phi$ such that

$$\tan \frac{1}{2} \phi = - \frac{1}{1 + \alpha} \cot \theta,$$

where $\alpha \equiv h/mc\lambda$.

Two methods of making this test suggest themselves. One is to use two point counters of the type developed by Geiger, Kovarik and others, one to receive the recoil electron and the other to catch the scattered quantum. The quantum hypothesis would predict simultaneous impulses in both chambers when set at the proper angles. This method has been employed by Mr. R. D. Bennett in our laboratory, and has recently been suggested also by Bothe and Geiger[1] as a means of testing Bohr's theory.

The second method, which Mr. Simon and I have been using, is to take cloud expansion photographs showing simultaneously a recoil electron and a secondary $\beta$-ray track produced by the scattered X-ray quantum. To increase the probability of emission of a $\beta$-ray by a scattered quantum, diaphragms of thin lead foil are placed inside the chamber. Thus about 1 in 50 of the recoil electrons is found to have a secondary $\beta$ particle associated with it.

Both methods have yielded provisional results. Mr. Bennett has connected each of a pair of head phones with one of the counting chambers

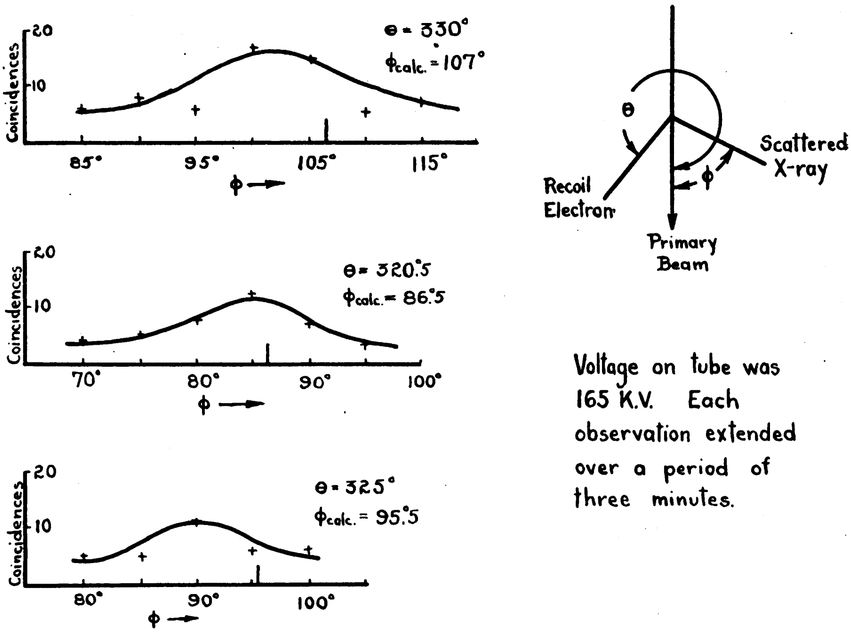


FIGURE 1

through a 3 stage amplifier, and has listened for simultaneous impulses in the two phones. He uses a thin strip of mica to scatter the X-rays, and places the counting chambers inside an evacuated vessel to avoid effects due to the curving of recoil electrons in air. His results for three different settings of the electron counter are shown in Figure 1. The fact that the coincidences are more frequent when the quantum counter is near the theoretical angle is in support of the quantum theory. Mr. Bennett hopes to be able to publish soon results obtained by a recording method, to avoid the uncertainties inherent in auditory observations of this type.

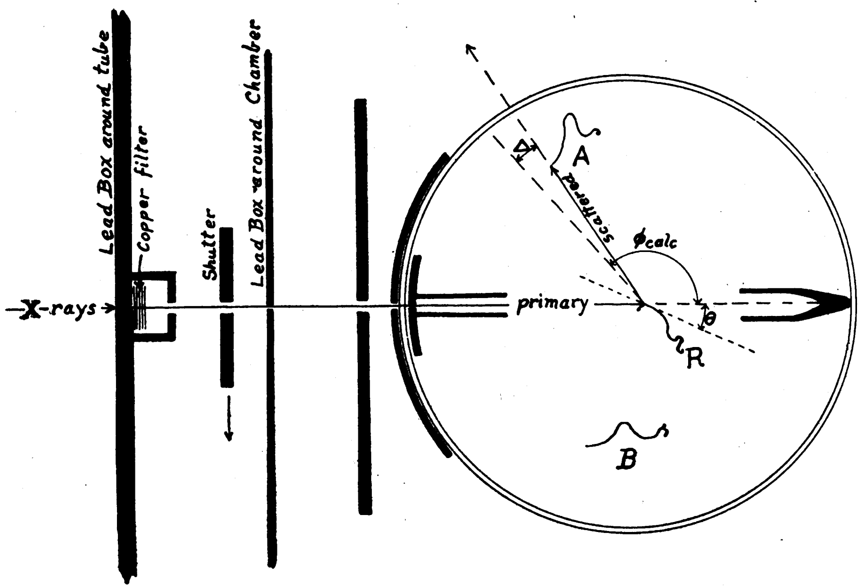


FIGURE 2

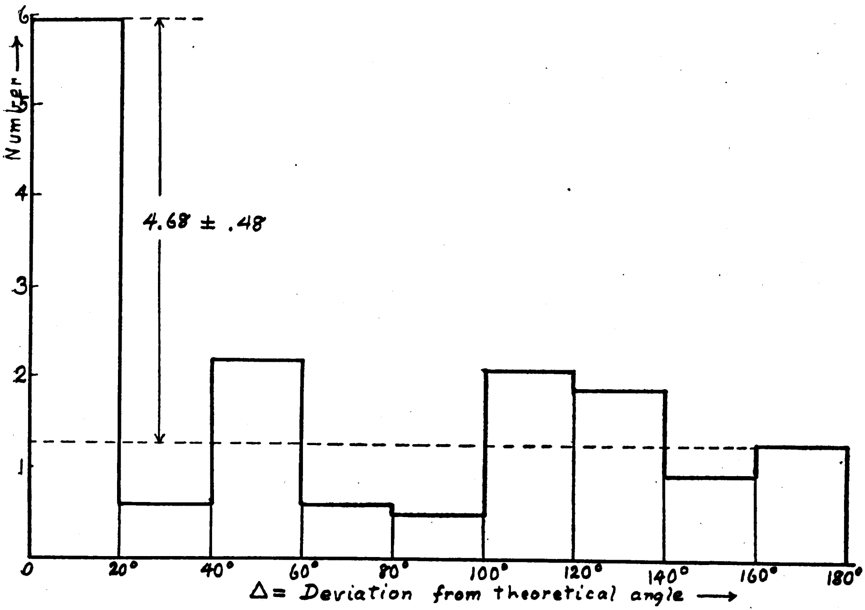


FIGURE 3

Mr. Simon and I have taken about 750 stereoscopic cloud expansion photographs, using apparatus such as that shown diagrammatically in figure 2. Our chief difficulty has been to eliminate stray X-rays, which give rise to meaningless tracks often indistinguishable from those due to scattered quanta. The results of the last 350 plates, in which these rays were reduced to a relatively low intensity, are shown in figure 3. Here I have plotted the deviation Δ of the observed tracks from the theoretical angle. On the spreading wave theory, the values of Δ should be nearly uniformly distributed between 0 and 180 degrees. On the quantum theory they should be concentrated near 0, as is obviously the case. The occurrence of tracks at other angles is explicable as due in part to stray X-rays and in part to the method of plotting the results.

A more detailed account of the work will be published when further experiments, which are now in progress have been completed. The results already obtained, however, permit us to state, with very little uncertainty, that the direction in which a quantum of scattered X-rays can produce an effect is determined at the moment it is scattered, and can be predicted from the direction of motion of the recoil electrons. In other words, *scattered X-rays proceed in directed quanta.*

It is possible to clothe this statement in the language of the wave-theory, if we keep in mind that a wave with a single quantum of energy can produce an effect in only one direction.[2]

[1] W. Bothe and H. Geiger, *Zeitschr. Physik.*, **26** (1924) 44.

[2] Since this paper was read before the Academy, I have received a letter from Dr. Bothe informing me that H. Geiger and he have also observed the coincidences demanded by the quantum theory but contrary to the theory of Bohr, Kramers and Slater. Their work will be described soon in *die Naturwissens haften.*

---

## *ETHER-DRIFT EXPERIMENTS AT MOUNT WILSON*

By Dayton C. Miller

Case School of Applied Science

Read before the Academy April 28, 1925

The Michelson-Morley Experiment to determine the relative motion of the earth and the luminiferous ether, "ether drift," was first performed in Cleveland, Ohio, in the year 1887.[1] The experiment is based upon the argument that the apparent velocity of light should be slightly different according to whether the observer is carried by the earth in the line in which the light is travelling, or at right angles to this line. The interferometer devised by Michelson is capable of showing very minute changes in the relative velocities of two beams of light. Simple theory shows that