

ture of the band is quite appreciable and is to be expected from such a slit.

Using the simple theory of diffraction for a single slit we find, that if the wave length for the molybdenum rays is 0.7\AA and the total width of the fringe is (at the position of the upper arrow in figure 1) 0.55 cm., then the slit width must be 0.0018 mm. If the width corresponding to the position of the lower arrow is taken where the width is 0.74 cm. then the slit width comes out 0.0013 mm. At the position where diffraction first definitely begins, the slit width to have produced that widening is 0.004 mm. This is in agreement with the work of Haga and Wind. As is now quite apparent, the great difficulty, once the fringe is obtained is to measure correctly the slit width corresponding to the point of measurement of the fringe width.

Even with the present decisive photograph it does not seem possible to obtain the wave-length of the X-rays with accuracy because of the above-mentioned difficulty.

In conclusion, I wish to express my appreciation for the help of Prof. A. H. Compton and for his kindness throughout the course of these experiments. My thanks are also due to the Eastman Kodak Co., of Rochester and to Mr. M'Ghee of the Sweet Wallack Co. of Chicago, for the enlargement of the photograph shown in figure 1.

NOTE: At the time of the publication of this paper Herr Walter (*Ann. Phys.*, Aug., 1924, and Sept., 1924) had just published two papers on the "Diffraction by a V-Slit" in which he found the effect which, before, Walter and Pohl had been unable to find. Their new measurements are with the long rays from copper (1.54\AA). It is interesting to note that in figure 1 the separation is complete and the fringe diverges in a fan-shape while in the photograph of Walter the first order bands do not diverge very much from the main band.

¹ Haga and Wind, *Ann. Physik.*, 68, 884, 1903; Walter and Pohl, *Ibid.*, 29, 331, 1909; Sommerfeld, "Atombau u. Spectral," pp. 118-120, 1919 ed.

² Irwin Isaac Rabinov, M.S., *Thesis*, University of Chicago, Nov., 1923.

THE COMPTON EFFECT WITH HARD X-RAYS

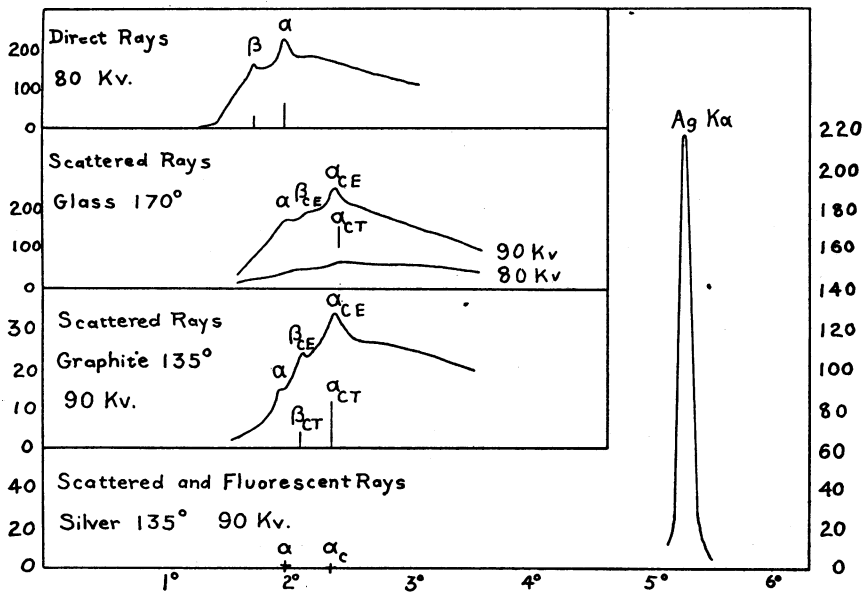
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In the researches on the Compton effect published to date, the region least known is that of hard X-rays, where recent statements as to its existence are quite conflicting. At the December meeting of the American Physical Society, we reported finding the Compton effect in hard rays, but the data covered so few cases, and those with such an unsatisfactory degree of accuracy, that we hoped to improve them before more detailed

publication. Unfortunately, however, the work was then unavoidably interrupted, so it seems advisable now to support our assertion for the existence of this effect by publishing what evidence we have, in spite of its incompleteness.

The spectrometer used in this work was an ionization instrument with a Dolezalek electrometer and a slit system in which the angular width of the beam was limited by two slits, one an ordinary lead slit, very near the scattering block, and the other a Seemann slit with a gold edge. In addition to these, there were five wider slits, or diaphragms, for stopping stray rays. This two-slit combination avoids any of the irregularities of intensity to which Soller slits would be liable if used at these very small glancing angles.



The tube was a special water-cooled tungsten-target tube with no bulb, the glass being a single cylindrical tube of 3.6 cm. diameter, enabling us to place the scattering block very close to the focus. In spite of its small diameter, however, this tube would stand potentials up to 90,000 volts. For the privilege of using this remarkable tube, we are indebted to the General Electric Co., and especially to Drs. Coolidge and Davey, who designed it and had it built for us.

The results of this preliminary survey are shown in figure 1. In this figure the upper graph is a direct-ray spectrum, obtained at 80 kv. during the process of seasoning the tube, and showing the tungsten *K*-series lines,

which were used as wave-length standards for locating the zero of the spectrometer scale.

The pair of graphs below this one were obtained with the rays scattered from glass, primarily the glass of the X-ray tube on the side farthest from the slits, but supplemented by a plate of glass beyond the tube. This scatterer has the disadvantage of heterogeneity of composition, especially as the plate unfortunately turned out to be lead glass; and it is also impossible to be sure that the glass in the nearer side of the tube in line with the slits was all in the shadow of the target. But it had the advantage of giving the strongest scattered rays obtainable, and this proving most conclusively the existence of the Compton peaks. In these curves, the experimental points are crowded together too closely to show on this scale, there being 45 of them in all. Their departures from the curve are almost all less than the width of the line used here to represent it, and the position of the shifted peak, α_{CE} , agrees to within two minutes of arc with the theoretical position, α_{CT} , an agreement probably within the limit of error. Incidentally, the shift of the continuous spectrum as a whole is of the order of magnitude predicted by Compton's theory.

The next graph, obtained with graphite, is not so accurate, because the available intensity is only about a fifth that obtainable from the glass. But still its 42 experimental points depart from it by only about 2 per cent, on the average, and all the peaks shown here are distinctly indicated by experimental points. Here the experimental shifted peak, α_{CE} , is again only two minutes of arc from the theoretical peak, α_{CT} , well within the limit of error.

In the case of silver, at the bottom of the figure, the α line of the fluorescent rays was the strongest secondary radiation we obtained from any of these substances, and presumably the β line would have proved strong, too, had we looked for it; but elsewhere in the spectrum the rays were too weak to detect, except possibly at or near the unshifted tungsten α position. There we obtained a faint radiation, impossible to measure accurately, but apparently about a two-hundredth as strong as the fluorescent rays. This is in very sharp contrast to the results of Clark and Duane,¹ but in complete agreement with results obtained photographically in 1914 by de Broglie,² who states that fluorescent spectra are almost free from "white" radiation, and it is likewise to be expected from the figures found in the classical researches by which Barkla³ discovered X-ray fluorescence.

In conclusion we must emphasize again the purely preliminary character of these results, and the fact that they are not accurate enough to warrant quantitative conclusions on the relative intensities of the peaks, although for glass and graphite they do demonstrate that the Compton effect exists and that the line showing the Compton shift is strong.

¹ G. L. Clark and W. Duane, these PROCEEDINGS, 10, 92, March, 1924.

² M. de Broglie, *Comptes Rendues Paris Acad. Sci.*, 158, 1493 (1914); *Journal de Physique* (July, 1916).

³ See especially *London Phil. Mag.*, 16, 550 (1908).

THE HEAT CAPACITY OF SOLID ALIPHATIC CRYSTALS

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The quantum theory of the heat capacity of solid substances, first developed for monatomic solids by Einstein and by Debye, has been extended to simple inorganic compounds (for example, the alkali halides), by Born and v. Karman and by Nernst.

An attempt will be made in this paper to apply the principles so far developed to the heat capacities of crystalline aliphatic compounds. No effort for a rigorous analysis will be made: the paucity of data and knowledge of these substances does not warrant it.

Born and v. Karman¹ have shown that the molecular heat of a polyatomic crystal is expressed by a combination of Debye and Einstein functions. Thus if we restrict our attention to moderate temperatures, we may write for a crystal whose molecule contains n atoms,

$$C_v = \sum_{j=1}^3 D'(\nu_j/T) + \sum_{j=4}^{3n} E'(\nu_j/T) \quad (1)$$

where D' and E' are Debye and Einstein functions, respectively, of a linear oscillator of frequency ν_j .

As the elastic properties of organic substances are not as yet available, and the Debye functions consequently undeterminable, it will be necessary to introduce some approximation. Since, in general, n is large for organic substances, and as the Debye function is usually not greatly different in value from the Einstein at ordinary temperatures, we may write

$$\sum_{j=1}^3 D' + \sum_{j=4}^{3n} E' = \sum_{j=1}^{3n} E' \quad (2)$$

and equation (2) will be expected, a priori, to give too low values for C_v at the lower temperatures, this being characteristic of Einstein functions.

Equation (2) is still, however, too ideal for use. Suppose each atom is regarded as vibrating in all directions with a mean frequency $\bar{\nu}_j$, then

$$\sum_{j=1}^{3n} E' = \sum_{j=1}^n f(\bar{\nu}_j/T) = C_v \quad (3)$$