The Elastic Scattering of High Velocity Electrons by Mercury Atoms and the Agreement with Mott's Theory

EDWARD B. JORDAN,* *University of California, Berkeley, California*

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The angular distribution of electrons scattered elastically by single mercury atoms has been studied for electrons of 900, 1160, 1600 and 2000 volts energy. The angle range was 8° to 48°. The values of the scattered intensities have been plotted and compared with the corresponding theoretical curves computed in accordance with Mott's theory. The theoretical and experimental curves for 900 volt-electrons differ markedly in shape. The slope of the experimental curve is much greater for small angles than that of the theoretical curve. The departure from Mott's curve decreases progressively for electron velocities corresponding to 1160, 1600 and 2000 volts energy. The 2000 volt curve shows good agreement with the corresponding theoretical curve.

THE scattering formula of Mott[1] $(e^4/4m^2v^4) \times (Z-F)^2 \operatorname{cosec}^4 \frac{1}{2}\theta$ gives an expression for the electron current scattered in a unit solid angle, in the direction θ, by a single free atom placed in a stream of unit electron current density. In this formula e is the charge on the electron, m its mass and v its velocity. Z is the atomic number of the scattering atom and F, a function of θ, is the atomic form factor.

The results of Dymond and Watson,[2] Harnwell,[3] McMillen,[4] Werner,[5] Hughes, McMillen and Webb[6] allow one to conclude that Mott's theory is adequate to describe the experimental facts for helium for energies above 200–400 volts. For mercury, Mott's theory was inadequate to describe the experimental facts for the highest energies used (700 volts) according to Tate and Palmer,[7] and Hughes.[8]

The purpose of the present research was to investigate the scattering by mercury atoms when higher velocity electrons were used and if possible to find at what voltage Mott's theory accurately accounted for the experimental data.

The apparatus used in this experiment was the same as that used by Jordan and Brode[9] in their measurements on the scattering of electrons by mercury vapor for low voltages. The apparatus was carefully aligned and only those measurements of the scattered current intensities which were the same on the two sides of the central beam were used. Each point shown on an experimental curve is the average of a number of measurements taken for the same scattering angle on the two sides of the central beam. Considerable precaution was taken to make sure that the electron beam was in the plane that passed through the center of the collector slit system.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the measurements are given in Fig. 1. No attempt was made to compute the absolute magnitude of the scattered intensities from the experimental measurements because the solid angle of collection was not accurately known. The ordinates consequently represent the scattered intensities in arbitrary units. The angular range studied was 8° to 48°. The scattered currents at larger scattering angles were too small to measure accurately when these higher voltages were used.

In order to plot the theoretical curves shown in the figures it was necessary to calculate the atomic structure factor F for mercury for this

* Whiting Fellow, University of California.

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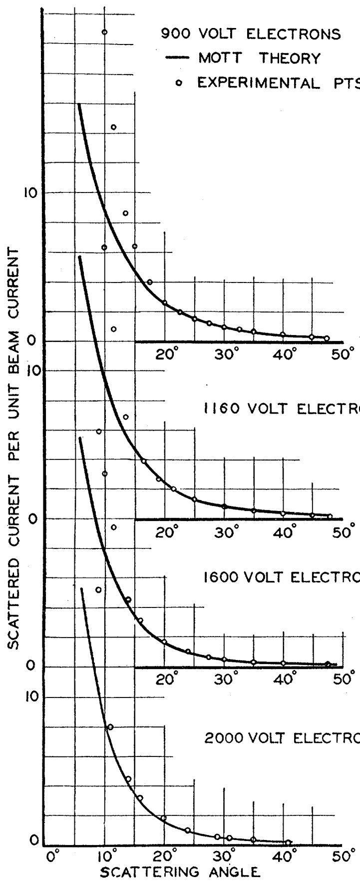

FIG. 1. Atomic scattering coefficient in arbitrary units.

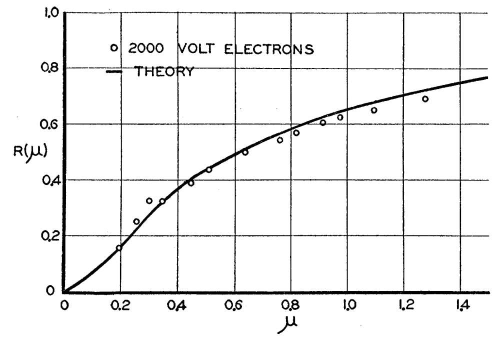

FIG. 2. $R(\mu)$, ratio of the actual scattered amplitude to the Rutherford amplitude, as a function of μ for mercury.

angular range. The F values for caesium together with a formula which enables one to calculate the F values for any other heavy element are given in James and Brindley's[10] paper. These data were used in the present calculations. The magnitudes of the experimental and corresponding theoretical curves have been adjusted so that the curves are in agreement at 30°. It is evident that theory does not account for the scattering of electrons by mercury atoms when the energy of the electrons is 900 volts or less. The slope of the experimental curve is much greater than that of the theoretical curve for the smaller angles. This is in accord with the results of Hughes, McMillen and Webb[6] for helium when the energy of the electrons was less than about 400 volts. The departure from Mott's curve decreases correspondingly for the 1160, 1600 and 2000 volt curves. The 2000 volt curve shows good agreement with the corresponding theoretical curve. Morse[11] has suggested another method for comparing the theoretical and experimental values. If $R(\mu)$, the ratio of the actual scattered amplitude to the Rutherford amplitude is plotted as a function of μ, $[\mu=\sin(\theta/2)/\lambda]$, where λ is the de Broglie wave-length, then the plot shown in Fig. 2 is obtained. The solid line is the theoretical curve, and the circles are the experimental points obtained using 2000 volt electrons. This method of comparison shows the agreement at larger angles to a better advantage.

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