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Diffraction of Matter.*

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MATTER is built up of two types of entities called "Electrons" and "Protons," the behaviour of which in large-scale electric or magnetic fields can be explained satisfactorily by assuming them to be particles with definite mass and electric charge subject to the ordinary laws of mechanics. But phenomena like spectral emission and the photoelectric effect cannot be explained on these lines. The new mechanics developed by De Broglie, Schrödinger, Heisenberg, Born and Dirac leads to the same result as classical mechanics in large-scale phenomena and, at the same time, solves the problems of atomic mechanics. In this new treatment called Wave Mechanics, a beam of electrons is represented by a wave train with a wave-length $\lambda = \frac{h}{mv}$ where h is Planck's constant, v is the velocity and m the mass of the individual electrons. The knowledge of the position of the electrons is represented by a "wave packet" or group of waves.

If electrons can be treated as waves, they ought to be diffracted by a lattice like the regularly arranged atoms in a crystal in very much the same way as X-rays and light. This was verified experimentally by G. P. Thomson, and Davisson and Germer almost simultaneously in 1928.

G. P. Thomson allowed a fine pencil of cathode rays from a discharge tube to pass through a very thin film of gold and then fall on a photographic plate. The apparatus was kept completely evacuated in order to prevent absorption of the electron beam. A ring pattern was produced on the photographic plate showing that the electron beam had been diffracted by the polycrystalline gold film. The wavelength calculated by assuming the lattice constant of gold agreed with that obtained from the relation $\lambda = \frac{h}{mv}$. This phenomenon of diffraction of electrons offers a method which has been successfully employed for the investigation of the structure of thin films, surface phenomena, the nature of polished surfaces and other allied problems.

Davisson and Germer used slow electrons from a hot filament, speeded up by applied potentials of between 60 and 600 volts, incident on one of the faces of a single crystal of nickel, the diffracted beam being detected by a moveable Faraday chamber. The position of the diffraction maxima was not quite what should be expected from theory. This discrepancy can be explained by assuming an "internal potential" for the crystal. This internal potential is found to be related to the electrical conductivity and is about 16 volts for nickel.

A fast electron beam falling on a small single crystal gives rise to an extended pattern of diffracted beams very much similar to those obtained with "crossed gratings" and monochromatic light. Using a thin sheet of mica, Kikuchi obtained a pattern similar to what would result from a two-dimensional grating of the type of a single sheet of atoms in the crystal. Condition for interference depends on two factors, the first of which is responsible for the cross grating effect and determines the position of the spots. The other factor depends on reinforcement of waves coming from points in a vertical row and the diffraction spots will be strong if this is strong and weak if this is weak. The second factor is obviously very small for extremely small crystals and comes into play for thicker crystals. The pattern obtained changes accordingly with the thickness of the crystal. Besides these factors the interaction of the incident and diffracted beams of electrons, which is absent in the case of X rays, has also to be taken into account for a rigorous explanation of these facts.

Electron diffraction offers an excellent weapon for the study of the structure of free molecules, *i.e.*, molecules in the gaseous state. X-ray analysis of crystals sometimes leads to the determination of the structure of molecules forming the crystal. But the method is laborious and depends on tiresome elimination of all interference phenomena arising from crystal symmetry. The molecules in gases and vapours, however, are sufficiently independent of one another to ascribe the intensity distribution obtained definitely to "intramolecular" interference unadulterated by "intermolecular" effects. Using a fast electron beam and a jet of vapour Wierl has studied the structure of CCl_4 and other tetrachlorides. The distances between carbon atoms obtained agree with those calculated from X-ray data. Electron diffraction thus offers a powerful weapon for testing molecular models.

Electron diffraction is a new method of analysis and the exploration of its possibilities is still in its initial stages. This is merely an attempt to give typical illustrations of the interesting effects produced by the diffraction of material waves.

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