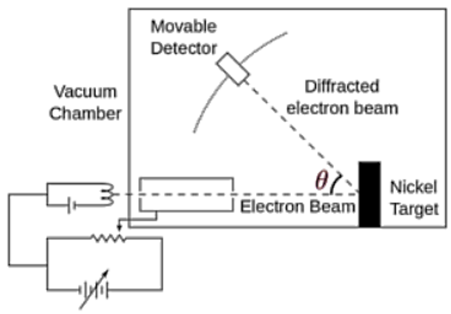
DUAL NATURE OF RADIATION

DAVISSON AND GERMER EXPERIMENT

DAVISSON AND GERMER EXPERIMENT

The apparatus for the Davisson and Germer experiment is contained within a vacuum chamber, ensuring the prevention of electron deflection and scattering by the surrounding medium. The key components of the experimental setup include:



The electron gun utilized in the experiment comprises a Tungsten filament, which emits electrons through thermionic emission, a process in which electrons are released when the filament is heated to a specific temperature. The experimental setup also incorporates an electrostatic particle accelerator, consisting of two plates with opposite charges (positive and negative), employed to accelerate the electrons to a known potential.

A collimator is employed to enclose the accelerator within a cylindrical structure, featuring a narrow passage along its axis for the electrons. The primary purpose of the collimator is to produce a focused, straight, and narrow beam of electrons, ensuring that it is well-prepared for the acceleration process.

The target employed in the experiment consists of a Nickel crystal, onto which the electron beam is directed perpendicularly. The positioning of the crystal allows for its rotation around a fixed axis, providing flexibility in the experimental setup.

A detector is integrated into the system to capture the electrons that are scattered by the Nickel crystal. This detector is designed to be movable along a semicircular arc, as illustrated in the accompanying diagram. The mobility of the detector enhances its capability to capture electrons scattered at various angles, facilitating a comprehensive analysis of the experimental outcomes.

The underlying concept behind the Davisson and Germer experiment stems from the idea that waves reflected from distinct atomic layers within a Nickel crystal will exhibit a consistent phase difference. Upon reflection, these waves can interfere either constructively or destructively, giving rise to a diffraction pattern.

In the experimental setup by Davisson and Germer, waves were metaphorically represented by electrons, which, in turn, manifested a diffraction pattern. This manifestation served as experimental confirmation of the dual nature of matter. The connection between the de Broglie equation and Bragg's law can be elucidated as follows:

Derived from the de Broglie equation, we express:

$$\lambda = h / p$$

$$= h / \sqrt{2mE}$$

$$= h / \sqrt{2meV} \qquad \ldots (1)$$

In this expression, m represents the mass of an electron, e denotes the charge on an electron, and h stands for Planck's constant.

Hence, for a specific value of V, an electron will possess a wavelength as determined by equation (1).

The Bragg's Law is expressed by the following equation:

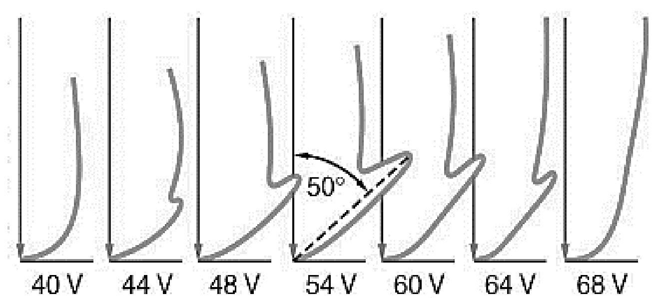
$$n\lambda = 2d \sin(90° - \theta/2) \qquad \ldots (2)$$

Given the known value of d obtained from X-ray diffraction experiments, the wavelength of waves generating a diffraction pattern can be determined for various values of θ using equation (2).

OBSERVATIONS OF THE DAVISSON AND GERMER EXPERIMENT

The detector utilized in this experiment is capable of detecting electrons solely as particles, registering their presence in the form of an electronic current. The study involves examining the intensity, or strength, of this electronic current received by the detector in relation to the scattering angle, referred to as the electron intensity.

The electron intensity of the scattered electrons exhibits a non-continuous pattern, displaying maximum and minimum values corresponding to the peaks and troughs of a diffraction pattern produced by X-rays. This behavior is observed at various scattering angles and potential differences. For a specific voltage, such as 54V, the maximum scattering occurs at a fixed angle, for example, 50°, as depicted below:



The outcomes derived from the Davisson and Germer experiment yield a measure for the scattering angle (θ) and the associated potential difference (V) at which electron scattering achieves its maximum. Utilizing these two values in equations (1) and (2) from the data amassed by Davisson and Germer results in identical values for the wavelength (λ). This robustly supports the concept of de Broglie's wave-particle duality and serves as confirmation for his equation, as illustrated below:

Beginning with equation (1), we obtain:

$$\lambda = h / \sqrt{2meV}$$

For V = 54 V, we have

$$\lambda = 12.27 / \sqrt{54} = 0.167 nm \quad \text{.... (3)}$$

Given that the value of 'd' determined from X-ray scattering is 0.092 nm, for a potential difference (V) of 54 V, and a scattering angle (θ) of 50°, substituting these values into equation (2), we obtain:

$n\lambda = 2\ (0.092\ \text{nm})\ \sin\ (90^0 - 50^0/2)$

For n = 1, we have:

$\lambda = 0.165$ nm .... (4)

Hence, the experimental findings closely align with the theoretical values obtained from the de Broglie equation, affirming the validity of equations (3) and (4) as supportive evidence for the de Broglie equation.