2. Wave aspect of Particles

2.1. De Broglie's Hypothesis: Matter waves

In 1923, The scientist named as De Broglie suggests that the concept of wave-particle duality. According to which all material particle should display a dual nature wave as well as particle.

The photon of frequency, ν has energy

$$E = h\nu \text{ and momentum, } P = \frac{E}{c} = \frac{h\nu}{c} = h/\lambda$$

De Broglie Proposed that material particle as well as Photons have follow wave-particle duality concept. The wavelength, λ associated with Particle is given by, $\boxed{\lambda = \frac{h}{P}}$ (De Broglie wavelength)

For particle of mass m and having velocity, v

$$\lambda = \frac{h}{mv}$$

DeBroglie was also guided by the analogy of the least action principle in mechanics with fermat's Principle in optics.

We can also write that $P = \frac{h}{\lambda} = \hbar K$

where $K = 2\pi/\lambda$, it is a propagation vector.

i) If $K.E$, $K = \frac{P^2}{2m}$, then De Broglie wavelength,

$$\lambda = \frac{h}{\sqrt{2mK}}$$

(ii) Interms of accelerating potential, $K.E = qV$

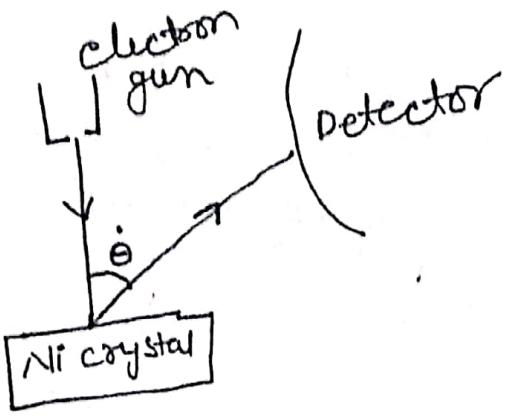
$$\lambda = \frac{h}{\sqrt{2mqV}}$$

2.2 Experimental verification of De Broglie's wavelength

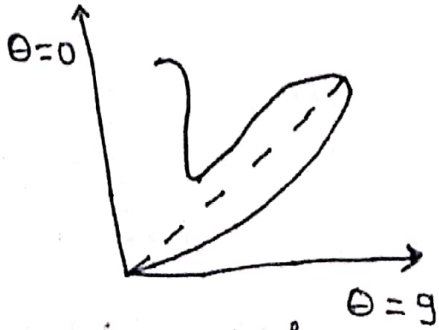
The de Broglie wavelength expression is experimentally established by Davisson-Germer.

Davisson - Germer Experiment

The experimental set up consist of electron gun having electron beam of various kinetic energy, directed normally to the surface of Nickel crystal.



The electron scattered in all possible direction. The intensity of scattered electrons was measured as a function of θ.



At each angle the intensity is given by the distance of point from origin in the polar plot.

The occurence of peak is explained on the basis of Bragg's diffraction law.

The Bragg condition for constructive interference is given by $n\lambda = 2d\sin\phi$

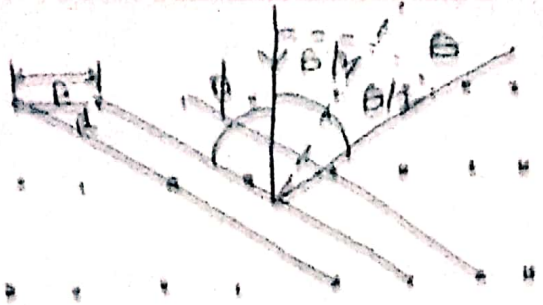


fig. Diffraction of electron waves from crystal

Where d is the interplanar spacing and n is an integer.

$$\phi + \theta + \phi = 180^\circ$$

$$\phi = \frac{180-\theta}{2} = 90 - \theta/2$$

from geometry

$$d = D \sin \theta/2$$

D refers to interatomic spacing, now bragg's law

$$n\lambda = 2D \sin\theta/2 \sin(90 - \theta/2)$$

$$= 2D \sin\theta/2 \cos\theta/2$$

$$= D \sin\theta$$

for Nickel, $D = 2.15\,\text{Å}$ and $\theta = 50^\circ$

$$\lambda = 2.15 \times \sin 50^\circ = 1.65\,\text{Å}$$

and according to De Broglie's

$$\lambda = \frac{12.3}{\sqrt{V}}\,\text{Å} = \frac{12.3}{\sqrt{54}} = 1.66\,\text{Å}$$

Thus the experiment results holds good for theortical result. This also conformed the variation of λ with momentum of electron.