SEM-IV
PHYH-C IX: ELEMENTS OF MODERN PHYSICS

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Matter waves, de Broglie wavelength

The phenomena like photoelectric effect, Compton effect or the emission of energy from hot cavity all these are explained on the basis of quantum theory of radiation. According to quantum theory of radiation, an electromagnetic radiation (i.e. light) behaves like quanta or photon particle of relativistic mass $\frac{h\nu}{c^2}$, velocity c and momentum $\frac{h\nu}{c}$.

But the photon theory failed to explained the phenomenon of interference and diffraction etc. These type of phenomena can be explained on the basis of wave theory of light.

Thus we can conclude that light and other electromagnetic radiation some times act like waves and some time likes particle. So light has a dual nature. it behaves like a wave in times of transmission and as a particle when it interacts with matter.

In 1924 de-Brogli proposed that material particles behave like waves on some occasions and it is experimentally verified by Davission and Germer 1927.

de-Brogli Hypothesis: A wave is always associated with every moving particle(like-electron) and its corresponding wavelength is given by

$$\lambda = \frac{h}{p} \tag{0.1}$$

where p is the momentum of the material particle and h is the Plank's constant λ is called de Brogli wavelength.

Proof:

Let us now consider the case of a photon with its mass m and rest mass m_0. According to the plank's quantum theory energy of the photon

$$E = h\nu$$

Now, for a relativistic particle , the square of the relativistic energy

$$E^2 = p^2c^2 + m_0^2c^4$$

$$E = p\,c$$

since photon rest mass $m_0 = 0$.

$$h\nu = p\,c$$

$$p = \frac{h\nu}{c}$$

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

this relation is hold good for elementary particles like electrons. Thus for an electron of mass m and velocity v de-Brogli wavelength.

$$\lambda = \frac{h}{m\,v}$$

de-Brogli wavelength of an electron subject to a potential difference V: Let us now consider an electron of mass m and charge e is subjected to a potential difference$V$ so that it acquires a velocity v, its K.E

$$E = \frac{1}{2}mv^2$$

In this case

$$eV = \frac{1}{2}mv^2 \qquad i.e \qquad v = \sqrt{\frac{2eV}{m}} \qquad i.e. \qquad v = \sqrt{\frac{2E}{m}}$$

If the de Brogli wavelength of this moving electron of momentum p isλ then

$$\lambda = \frac{h}{p} \qquad i.e. \qquad \lambda = \frac{h}{m\,v}$$

after substituting the velocity $v$we can get

$$\lambda = \frac{h}{m\sqrt{\frac{2eV}{m}}}$$

We can write another form as

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

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

after substituting the values of h,m,e one can get

$$\lambda = \frac{12.26}{\sqrt{V}}A^0$$