Matter Waves

1) Dual nature of matter: de Broglie's hypothesis

1. a) In 1924, Louis de Broglie proposed that matter should also possess dual nature as radiation exhibits dual nature.

b) His hypothesis is based on two facts.

1) The whole energy in the universe is in the form of matter and energy i.e.., matter and energy are the manifestations of the same. So these two forms of energy should possess similar characteristics,

2) Nature is symmetrical in many ways. As light has dual nature, matter should also possess dual nature.

c) The wavelength λ of the wave associated with a matter particle of mass m moving with velocity is given by $\lambda = \frac{h}{P} = \frac{h}{mv}$. This relation is known as *de Broglie relation.*

d) de Broglie wavelength of a particle is independent of the nature of the material.

e) de Broglie waves are not electromagnetic waves.

f) They do not move with the velocity of light, and are not produced by charged particles.

g) If a large number of waves of frequencies differing by very small amounts are superimposed, a *wave packet* is formed which will have the same velocity as the particle.

h) A moving particle is always associated with a wave packet rather than a wave.

i) Electromagnetic radiation consists of particle-like discrete bundles of energy called photons or light quanta.

2. **Properties of photon**

i) The rest mass of a photon is zero while the mass of a moving photon is $\frac{h\nu}{c^2}$ or $\frac{h}{c\lambda}$.

ii) The energy of photon (E) = $h\nu = \frac{hc}{\lambda}$ where

h = Planck's constant.

iii) The momentum of a photon (P) = $\frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$.

iv) The effective mass of a photon

(m) = $\frac{E}{c^2} = \frac{h\nu}{c^2} = \frac{h}{\lambda c}$.

v) The intensity of a beam of photons

$$(I) = \frac{\text{energy}}{\text{area x time}}$$

$$= \frac{\text{energy of a photon x number of photons}}{\text{area x time}}$$

3. **de-Broglie wavelength in different forms**

i) If a material particle is moving with velocity ν and kinetic energy E we have

$$E = \frac{1}{2}m\nu^2 = \frac{P^2}{2m}$$

$$\Rightarrow P = \sqrt{2mE}$$

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

ii) If a charged particle (q) is accelerated by a potential difference of V, then

$$\frac{P^2}{2m} = qV$$

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

iii) de–Broglie's wave lengths associated with different particles

a) Electron = $\lambda_{electron} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$ (or)

. $\lambda_{electron} = \frac{12.27}{\sqrt{V}}$ A°

b) Proton: $\lambda_{proton} = \frac{0.286}{\sqrt{V}}$ A°0.

c) Deutron: $\lambda_{deutron} = \frac{0.202}{\sqrt{V}}$ A°

d) α - particle: $\lambda\alpha = \frac{0.101}{\sqrt{V}}$ A°

e) Neutron: $\lambda_{neutron} = \frac{0.286}{\sqrt{E}}$ A°

iv) If a material particle is in thermal equilibrium at temperature T, its kinetic energy is given by

$$K.E = \frac{P^2}{2m} = \frac{3}{2}KT \Rightarrow \lambda = \frac{h}{P} = \frac{h}{\sqrt{3mKT}}$$

4. From Davisson – Germer experiment we conclude that d sinθ = nλ