de-Broglie Hypothesis

❖ Introduction

- ❖ Light behaves like a wave in the phenomena of interference, diffraction, and polarization.
- ❖ The same light also behaves like a particle in the photoelectric effect and the Compton effect.
- ❖ Hence, light has a **dual nature –** it exhibits both wave and particle characteristics.

❖ de-Broglie hypothesis:

- ❖ In 1924, **Louis de-Broglie** proposed that, just like light, matter should also exhibit a dual nature i.e., both wave and particle.

❖ de-Broglie Waves or Matter Waves

- ❖ The wave associated with a moving particle is called a **matter wave** or **de-Broglie wave**.
- ❖ Every moving particle is associated with a wave, which is known as a matter wave (or de-Broglie wave).

❖ de-Broglie Wavelength

- ❖ The wavelength associated with matter waves is called the **de-Broglie wavelength**.
- ❖ For a particle of mass m moving with velocity v, the de-Broglie wavelength is:

$$\lambda = h/mv$$

- ❖ Where h = Planck's constant.

❖ Derivation of de-Broglie Wavelength

- ❖ **From Planck's theory, the energy of a photon of wavelength λ is**

$E=h\nu$

$E = hc/\lambda$ ....(1)

- **From Einstein's mass–energy relation is**

$E=mc^2$ .... (2)

- From (1) and (2): $mc^2 = hc/\lambda$

$\lambda = h\not{c}/mc^{\not{2}}$

$\lambda = h/mc$ ....(3)

- For a particle of mass m moving with velocity v

$\lambda = h/mv$

$\lambda = h/p$ ....(4)

de-Broglie Wavelength in terms of Kinetic Energy(k)

- For a particle of mass m moving with velocity v, then its kinetic energy is

$K=mv^2/2$

$K= m^2v^2/2m$

$K= P^2/2m$

$P^2 = 2mK$

$P = \sqrt{2mK}$ ....(5)

- From (1) and (2): $\lambda = h/\sqrt{2mK}$ ....(6)

de-Broglie Wavelength in terms of Potential difference(V)

- If a particle of charge **e** is accelerated through a potential difference **V**, then its kinetic energy is $K=eV$

- From (6): $\lambda = h/\sqrt{2meV}$ ....(7)
- Where: $h= 6.625 \times 10^{-34}$ JS, $m=9.11 \times 10^{-31}$ kg and $e= 1.6 \times 10^{-19}$ c

$\lambda = 6.625 \times 10^{-34} / 5.399 \times 10^{-25}(\sqrt{V})$

$\lambda = 12.27 \text{ X } 10^{-10} / \sqrt{V}$

$\boldsymbol{\lambda = 12.27 / \sqrt{V}}$ A^0 ....(8)

❖ Properties of Matter Waves

❖ **1.Wavelength: $\lambda = h/mv$**

❖ If v=0, then $\lambda = \infty$ (infinity)

→ A particle at rest does not have an associated matter wave.

❖ For large **m**, the de-Broglie wavelength is extremely small.

→ That is why matter waves are not observed in everyday life.

❖ **2.Velocities of Matter Waves:**

Matter waves are characterized by two velocities:

❖ ***Phase Velocity (v_p):***

❖ The velocity of a single independent wave is called **phase velocity.**

❖ It is given by $\mathbf{v_p} = \omega/k$

❖ For matter waves, $\mathbf{v_p} < c$.

❖ *It always greater than speed of light in air or vacuum*

❖ ***Group Velocity (v_g):***

❖ The velocity of a wave packet is called **group velocity**.

❖ It is given by $v_g = d\omega/dk$

❖ For matter waves, $v_g < c$.

❖ **3.A matter wave is not an electromagnetic wave.**

❖ **4.A particle does not exhibit wave nature and particle nature simultaneously.**

❖ **5.Due to wave nature, the principle of uncertainty is also applicable to matter particles.**