1.6.HEISENBERG's UNCERTAINTY PRINCIPLE(HUP)

Introduction:

- Werner Heisenberg proposed a very interesting principle in 1927, which is a direct consequence of the dual nature of matter (wave-particle duality), known as HUP.

Statement:

- It is impossible to measure both the position and momentum of a particle simultaneously to any desired degree of accuracy.

Qualitative Explanation:

- The product of the uncertainties in the knowledge of position and momentum must be at least on the order of Planck's constant (h).

Mathematical Expression:

- More precisely, "The product of uncertainties in determining the position and momentum of the particle is never smaller than h/4π.
- **Therefore**, $\Delta x \cdot \Delta p_x \geq h/4\pi$ -----------(1)

(OR)

$\Delta x \cdot \Delta p_x \geq \hbar/2$ ---------(2) (since $h/2\pi = \hbar$)

where: Δx is the uncertainty in position

Δp_x is the uncertainty in momentum

h is Planck's constant

Explanation:

(i) If $\Delta x = 0$:

$\Delta x \cdot \Delta p_x = h/4\pi \Rightarrow \Delta p_x = h/4\pi\Delta x$

$\Delta p_x = h/4\pi.0$

$\Delta p_x = h/0$

$\Delta p_x = \infty$ ----------(3)

Therefore, the position of a particle is measured accurately ($\Delta x = 0$), then the uncertainty in its momentum becomes infinite ($\Delta p_x = \infty$).

(ii) If $\Delta p_x = 0$:

$\Delta x \cdot \Delta p_x = h/4\pi \Rightarrow \Delta x = h/4\pi\Delta p_x$

$\Delta x = h/4\pi.0$

$\Delta x = h/0$

$\Delta x = \infty$ -------------(4)

Therefore, the momentum of a particle is measured accurately ($\Delta p_x = 0$), then the uncertainty in its position becomes infinite ($\Delta x = \infty$).

Significance:

- The Heisenberg uncertainty principle is significant for microscopic particles.
- It implies that the energy of a photon does not significantly affect the position and velocity of large objects.

Applications:

(i)It helps in calculating the energy of a particle in a potential box.

(ii)It proves the non-existence of electrons in the nucleus.

(iii)It proves the existence of protons/neutrons in the nucleus.

(iv)It calculates the binding energy of an electron in an atom.

(v)Calculating the radius of Bohr's orbit in an atom.

(vi)It determines the frequency of radiation emitted by an excited atom.