Bohr's Postulates of Hydrogen atom:

Bohr's model for the hydrogen atom is based on the following postulates:

(i) The electron in the hydrogen atom can move around in the nucleus in a circular path of fixed radius and energy. The path is called orbits, stationary states or allowed energy states. These orbits are arranged concentrically around the nucleus.

(ii) The energy of an electron in the orbit does not change with time. However, the electron will move from a lower stationary state to a higher stationary state when required amount of energy is absorbed by the electron or energy is emitted when electron moves from higher stationary state. The energy does not take place in a continuous manner.

(iii) The frequency of radiation absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE, is given by:

$$n = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$$

Where E_1 and E_2 are the energies of the lower and higher allowed energy states respectively. This expression is commonly known as Bohr's frequency rule.

(iv) The angular momentum of an electron is quantized. In a given stationary state it can be expressed as-

$$m_e \, v r = n . \frac{h}{2\pi} \quad n = 1,2,3.....$$

Where m_e is the mass of electron, v is the velocity and r is the radius of the orbit in which electron is moving. Thus, an electron can move only in those orbits for which its angular momentum is integral multiple of $h/2\pi$. That means angular momentum is quantized.

Limitations of Bohr's Model:

(i). It fails to account for the finer details (doublet, that is two closely spaced lines) of the hydrogen atom spectrum observed by using sophisticated spectroscopic techniques. This model is also unable to explain the spectrum of atoms other than hydrogen.

(ii). It could not explain the ability of atoms to form molecules by chemical bonds.

Dual Nature of Matter and Radiation:

Wave theory of electromagnetic radiations explained the phenomenon of interference, diffraction and polarization. On the other hand, quantum theory of electromagnetic radiations successfully explained the photoelectric effect, Compton effect, black body radiations, X- ray spectra, etc. Thus, radiations have dual nature. i.e. wave and particle nature. Louis de Broglie suggested that the particles like electrons, protons, neutrons, etc have also dual nature. i.e. they also can have particle as well as wave nature.

According to de Broglie, a moving material particle can be associated with a wave. i.e. a wave can guide the motion of the particle. The waves associated with the moving material particles are known as de Broglie waves or matter waves.

Expression for de Broglie wave:

According to quantum theory, the energy of the photon is $E = h\nu = hc/\lambda$ …………(1)

According to Einstein's theory, the energy of the photon is $E = mc^2$ ………………..(2)

Combining equation (1) & (2), we get

$\lambda = h/mc$

or $\lambda = h/p$

where $p = mc$ is momentum of a photon.

If instead of a photon, we have a material particle of mass m moving with velocity v, then the equation becomes $\boldsymbol{\lambda = h/mv}$

which is the expression for de Broglie wavelength.

Conclusion:

(i). de Broglie wavelength is inversely proportional to the velocity of the particle. If the particle moves faster, then the wavelength will be smaller and vice versa.

(ii). If the particle is at rest, then the de Broglie wavelength is infinite. Such a wave cannot be visualized.

(iii). de Broglie wavelength is inversely proportional to the mass of the particle. The wavelength associated with a heavier particle is smaller than that with a lighter particle.

(iv). de Broglie wavelength is independent of the charge of the particle.

Heisenberg Uncertainty Principle:

Statement of the Principle: It is impossible to measure simultaneously both the position and momentum (or velocity) of a microscopic particle with accuracy or certainty.

Mathematically, this principle may be put as "the product of uncertainty in momentum (ΔP) is constant. The value of constant was found to be $h/4\pi$.

Thus, Heisenberg's uncertainty principle may be expressed as: $\Delta x.\Delta p \geq h/4\pi$

Since $p = mv$, $\Delta p = m\Delta v$

$\Delta x(m\Delta v) \geq h/4\pi$

Where, Δv is the uncertainty in velocity of the particle having mass, m.