❑ Spectral Series of Hydrogen atom:

1. Lyman series: It appears when an electron jumps from the outer orbits to the first orbit.
   (i.e., from n = 2, 3, 4, ……… to n = 1).
2. Balmer series: It appears when an electron jumps from the outer orbits to the second orbit.
   (i.e., from n = 3, 4, 5, ……… to n = 2).
3. Paschen series: It appears when an electron jumps from the outer orbits to the third orbit.
   (i.e., from n = 4, 5, 6, ……… to n = 3).
4. Bracket series: It appears when an electron jumps from the outer orbits to the fourth orbit.
   (i.e., from n = 5, 6, 7, ……… to n = 4).
5. Pfund series: It appears when an electron jumps from the outer orbits to the fifth orbit.
   (i.e., from n = 6, 7, 8, ……… to n = 5).

Problem: Calculate the radius of the hydrogen atom. Calculate the velocity of the electron in the first Bohr orbit in hydrogen atom. [Given, $h = 6.624 \times 10^{-34}\,\mathrm{J-s}$, $\epsilon_o = 8.85 \times 10^{-12}\,\frac{\mathrm{C}^2}{\mathrm{N-m}^2}$, $m = 9.1 \times 10^{-31}\mathrm{kg}$, $e = 1.6 \times 10^{-19}\mathrm{C}$].

Solution: Radius of hydrogen atom

$$r = \frac{\epsilon_o n^2 h^2}{\pi m Z e^2}$$

$$\therefore\ r = \frac{8.85 \times 10^{-12} \times (1)^2 (6.624 \times 10^{-34})^2}{3.141 \times 9.1 \times 10^{-31} \times 1 \times (1.6 \times 10^{-19})^2}$$

or, $r \cong 5.3 \times 10^{-11}\mathrm{m}$

$\therefore\ r = 0.53$ Å [$\because$ 1Å $= 10^{-10}\mathrm{m}$]

Here, $n = 1, Z = 1$

$h = 6.624 \times 10^{-34}\,\mathrm{J-s}$

$\epsilon_o = 8.85 \times 10^{-12}\,\frac{\mathrm{C}^2}{\mathrm{N-m}^2}$

$m = 9.1 \times 10^{-31}\mathrm{kg}$

$e = 1.6 \times 10^{-19}\mathrm{C}$

Velocity, $v = \frac{Ze^2}{2\epsilon_o nh}$

$$\therefore v = \frac{1 \times (1.6 \times 10^{-19})^2}{2 \times 8.85 \times 10^{-12} \times 1 \times 6.624 \times 10^{-34}}$$

$$= 2183465\ \mathrm{ms}^{-1}$$

$$\cong 2.2 \times 10^{6}\ \mathrm{ms}^{-1}$$

$$\cong 2200\ \mathrm{km}s^{-1}$$

Problem: Calculate the energy required to excite the hydrogen atom from the ground state (n = 1) to the first excited state (n = 2).

Solution: Energy required

$$E = \frac{mZ^2e^4}{8\epsilon_o^2h^2}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$= \frac{me^4}{8\epsilon_o^2h^2}\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$= \frac{me^4}{8\epsilon_o^2h^2}\left(1 - \frac{1}{4}\right)$$

$$= \frac{3me^4}{32\epsilon_o^2h^2}$$

$$= \frac{3 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^4}{32 \times (8.85 \times 10^{-12})^2 \times (6.624 \times 10^{-34})^2}$$

$$\therefore\ E \cong 1.6269 \times 10^{-18}\ \mathrm{J}$$

$$\cong 10.17\ \mathrm{eV} \qquad [\because 1\ \mathrm{eV} = 1.6 \times 10^{-19}\ \mathrm{J}]$$

Here, $n_1 = 1, n_2 = 2, Z = 1$

$$m = 9.1 \times 10^{-31}\mathrm{kg}$$

$$e = 1.6 \times 10^{-19}\mathrm{C}$$

$$\epsilon_o = 8.85 \times 10^{-12}\ \frac{\mathrm{C}^2}{\mathrm{N-m}^2}$$

$$h = 6.624 \times 10^{-34}\ \mathrm{J-s}$$

❑ Wave-particle duality:

The earliest theory for explaining the nature of light radiations was the corpuscular theory of Newton. However, Huygen's wave theory could explain satisfactorily the phenomena of interference, diffraction, double refraction, and polarization. The quantum theory of radiation was helpful in explaining the phenomenon of photoelectric effect.

Einstein suggested that the waves merely serve as guides for photons carrying the energy $h\nu$ for a frequency ν. This suggestion however brought a new and difficult concept to explain the various experimental data.

De-Broglie, in 1929, suggested that like photon, the material particles should be associated with some form of wave motion. De-Broglie hypothesis suggests that such wave existed and he called them matter waves. This point of view was used to explain quantization principles employed in explaining the hydrogen atom. This was further verified by Davisson and Germer through their electron diffraction experiments. The results positively conclude the existence of a system of waves associated with an electron beam. This new theory of the coexistence of waves and particles was fully developed subsequently by Schrodinger, Heisenburg, Dirac, and Maxborn. This led to the foundation of wave mechanics.