Chapter 3

Structure of Atom

BOHR'S ATOMIC MODEL

The model is based on the quantum theory of radiation and the classical concept of physics.

Postulate

(a) The path of electron is circular. The force of attraction between nucleus and electron is equal to centrifugal force of the moving electron.

(b) Electron can revolve only in those orbits whose angular momentum is an integral multiple of $\frac{h}{2\pi}$. *i.e.*, $mvr = \frac{nh}{2\pi}$. (m = mass of electron, v = velocity of electron, r = radius of orbit)

(c) Electron remains in stationary orbit where it does not lose energy.

(d) Each stationary orbit is with definite amount of energy (E) and $E_1 < E_2 < E_3$ .... Similarly $(E_2 - E_1) > (E_3 - E_2) > (E_4 - E_3)$.

The Energy of Electron

Total energy (E) = K.E. + P.E.

$$E_n = -\frac{2\pi^2 Z^2 me^4}{n^2h^2}\cdot K^2$$

where, n = 1, 2, 3 ....

E = Energy of electron in n^{th} orbit

Z = Nuclear charge

e = Charge of electron

m = Mass of electron

h = Planck's constant

i.e., $E_n = E_1 \times \frac{Z^2}{n^2}$ for H-like atom

H like atoms means atom which consists of one electron.

i.e., $E = -\dfrac{21.79 \times 10^{-19} Z^2}{n^2}$ J/atom

$= -\dfrac{13.6}{n^2} Z^2$ eV per atom

$= -\dfrac{313.6 \times Z^2}{n^2}$ kcal/mol

$= -\dfrac{1312 \times Z^2}{n^2}$ kJ/mol

Potential energy = 2 × E

Kinetic energy = – E

Total energy = E

Note : *If an atom consists more than one electron, then we take shielding effect into account.*

Radii of Orbits

$$r = 0.529 \frac{n^2}{Z} \text{ Å}$$

For H-like atoms. Thus $r_n = r_1 \times n^2$

Velocity of Electron

$$v = 2.188 \times 10^8 \times \frac{Z}{n} \text{ cm/s}$$

Number of revolution per second (Frequency)

$$N = \frac{V}{2\pi r} = 6.6 \times 10^{15} \frac{Z^2}{n^3}$$

Rydberg Equation

The wavelength (λ), wave number ($\bar{\nu}$) for the electromagnetic radiation can be calculated by Rydberg equation.

$$\bar{\nu} = \frac{1}{\lambda} = R_H \times Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Z = Atomic number

R_H = Rydberg constant = 109677 cm^{-1}

n_2 = Higher orbit

n_1 = Lower orbit

Total number of spectral lines

(i) $\frac{n(n-1)}{2} \rightarrow$ when electron jumps from n^{th} level to ground level.

(ii) $\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2} \rightarrow$ when electron returns from n_2 to n_1.

(iii) $\Sigma n_2 - n_1 \rightarrow$ when electron returns from n_2 to n_1.

(iv) $n_2 - n_1 \rightarrow$ number of spectral line in a particular shell.

> ***Note :*** *Remember in this case n_1, n_2 are energy level or orbit number. If we have given n^{th} excited state then formula will be different.*

$\frac{n(n-1)}{2}$ formula is applicable, if hydrogen sample contains several number of H atoms.

DUAL NATURE OF MATTER : de-Broglie Equation

(a) Louis de Broglie proposed that the material particles are also associated with wave nature, just as radiations.

(b) The wavelength of the wave associated with a particle mass 'm' moving with velocity 'v' as $\boxed{\lambda = \frac{h}{mv}}$.

where λ = de-Broglie wavelength

h = Planck's constant = 6.62×10^{-34} J-s.

> ***Note :*** *The waves associated with material particles or objects in motion are called* ***matter waves*** *or* ***de-Broglie waves.***

(c) Number of revolutions per second by an electron in a shell may be given as = $\frac{\text{Velocity}}{2\pi r} = \frac{v}{2\pi r}$

(d) de-Broglie's equation and K.E.

Let K.E. of the particle of mass 'm' is E

$$E = \frac{1}{2}mv^2$$

$$2Em = m^2v^2$$

$$\sqrt{2Em} = mv = P$$

$$\lambda = \frac{h}{P} = \frac{h}{\sqrt{2Em}}$$

Suppose an electron makes n wave in one complete circle, then $2\pi r = n\lambda$

QUANTUM NUMBERS

The set of four integers required to define the state of electron in an atom are called **quantum numbers.** The quantum numbers are

(1) Principal quantum number (*n*)

(2) Azimuthal quantum number (*l*)

(3) Magnetic quantum number (*m*)

(4) Spin quantum number (*s*)

(1) Principal quantum number, (*n*), relates to the amplitude (*i.e.*, size) of an electron wave and also the total energy of the electron. It has integral values of 1, 2, 3, 4 ... etc., also denoted as K, L, M, N .... etc.

(2) Azimuthal quantum number, (*l*), tells us about the subenergy shell of electron. For each main energy shell there can be '*n*' number of subenergy shells. These subenergy shells are designated by different values of *l*. For each value of *n*, *l* can have values from 0, 1, 2, 3 ... *n* – 1.

(3) Magnetic quantum number, (*m*), explains the behaviour of an electron in the external magnetic field or in other words it tells us about orbitals of the electrons. The values of m gives the number of orbitals associated with a particular sub shell in shell. For each value of l, m can have values from –*l* to +*l* including zero.

e.g., when *l* = 1, m = –1, 0, +1; *l* = 2, m = –2, –1, 0, +1, +2

(4) Spin quantum number, (*s*), gives an idea about the electron spinning on its axis. Each spinning electron can have two values of $+\frac{1}{2}$ or $-\frac{1}{2}$.

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