BIOMENTORS CLASSES ONLINE

PHYSICS CLASS NOTES

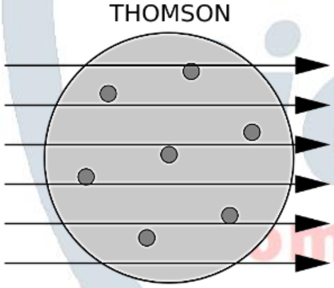
TOPIC: ATOMS **Lecture No.: 01**

Atoms: The smallest indivisible particle.

(1) Dalton's Atomic Theory

1. Every matter is made of small tiny particles called as atoms.
2. Atoms cannot be divided further
3. Atom is stable entity
4. Atom is electrically neutral
5. For a same material all atoms present will be identical But will be different for different materials.
   Ex. cu, Zn
6. Atom is smallest entity which participates in a chemical reaction and remains unaltered but can combine with other atoms to form different substances.

(2) Thomson's Atomic Model (Plum Pudding model and water melon model) – Atom is like a watermelon. Although atom is electrically neutral. Entire +ve charge is spread throughout atom like a pulp in water melon and –ve charge is embedded into it like seed in watermelon.

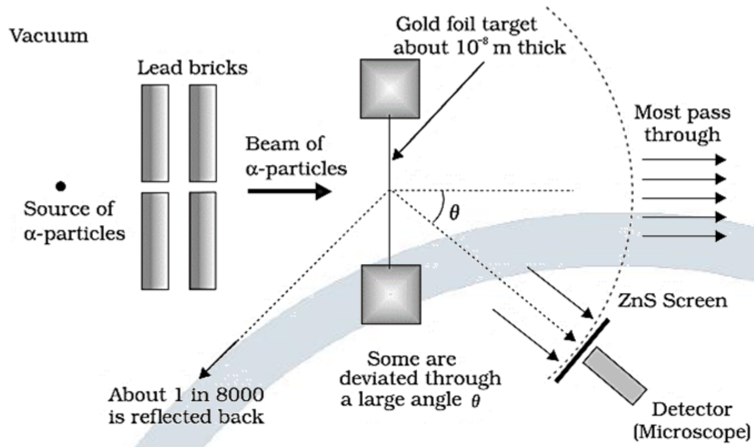


(3) Rutherford's Atomic model: (Planetary Model] – All the mass and +ve charge is situated at the centre of atom like sun and –ve charge i.e. electrons revolve around it in circular orbits like planets revolve around sun.

α-particle scattering experiment –

Observation of α – particle scattering experiment –

1. Most of α – particles go straight without any deviation
2. Some of α – particles are deviated from its path by some angle
3. 1 out of 8000 α – particle, deviated more than 90° & returns in backward direction.
4. Occasionally 1 out of millions returned back to same path

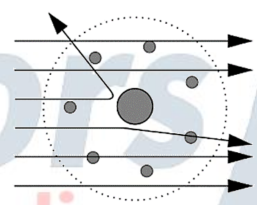


Conclusions –

1. Since most of α –particle go straight without any deviation it means most of the space inside atom is empty.
2. Since one out of 8000 α – particles, returning back, it means most of its mass & +ve charge is situated at centre.
3. Occasionally one out of millions is returning back to same path it means definitely entire +ve charge and whole of mass of atom is located at centre.
4. Negatively charge electrons are revolving around this +ve charge.

No of α-particle scattered –

$$N \propto \frac{1}{\sin^4\left(\frac{\theta}{2}\right)}$$



$\theta \rightarrow$ Scattering angle

N = no of α – particles scattered per minute.

Ex. **100 α – particles are being scattered at 60° then no of α- particle scattered at 90° will be?**

Sol.

$$N \propto \frac{1}{\sin^4\left(\frac{\theta}{2}\right)}$$

$$\Rightarrow \frac{N_1}{N_2} = \left[\frac{\sin\left(\frac{\theta_2}{2}\right)}{\sin\left(\frac{\theta_1}{2}\right)}\right]^4$$

$$\Rightarrow \frac{100}{N_2} = \left[\frac{\sin\left(\frac{90}{2}\right)}{\sin\left(\frac{60}{2}\right)}\right]^2$$

$$\Rightarrow \frac{100}{N_2} = \left[\frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}}\right]^4$$

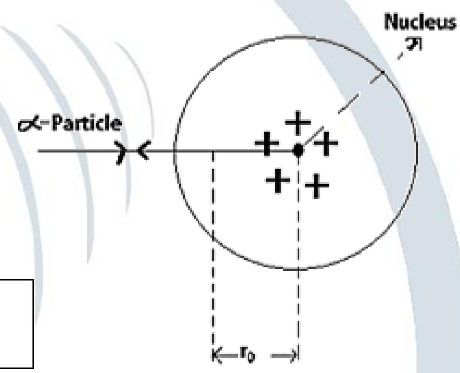
$$\Rightarrow \frac{100}{N_2} = [\sqrt{2}]^4$$

$$\Rightarrow \frac{100}{N_2} = 4$$

$$\Rightarrow N_2 = 25$$

Distance of closet approach – The shortest distance between atom & α – particle upto which α – particle reaches before returning back.

KE given to α – particle = PE of system of α – particle & atom



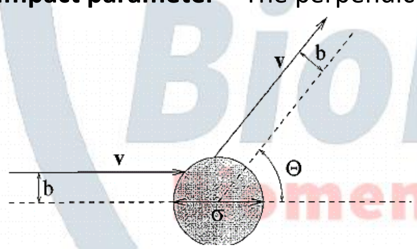
$$k_\alpha = \frac{1}{4\pi\epsilon_0} \cdot \frac{(q)Ze}{r_0}$$

$$\Rightarrow r_0 = \frac{q.Ze}{4\pi\epsilon_0.K_\alpha}$$

$$\Rightarrow r_0 = \frac{(2e)(Ze)}{4\pi\epsilon_0.K_\alpha}$$

$$\boxed{r_0 = \frac{2Ze^2}{4\pi\epsilon_0 k_\alpha}}$$

Impact parameter – The perpendicular distance of velocity vector from centre of nucleus.



$$\cot\left(\frac{\theta}{2}\right) = \frac{2b}{r_0}$$

θ = Angle of scattering

b = Impact parameter

r_0 = distance of closest approach

$$\cot\left(\frac{\theta}{2}\right) = \frac{2b}{r_0}$$

$$r_0 = \frac{2Kze^2}{k_\alpha}$$

$$\cot\left(\frac{\theta}{2}\right) = \frac{2b}{\frac{2Ze^2}{4\pi\epsilon_0 k_\alpha}}$$

$$\Rightarrow \cot\left(\frac{\theta}{2}\right) = \frac{4\pi\epsilon_0 . k_\alpha}{ze^2}$$

$$\Rightarrow b = \frac{ze^2}{4\pi\epsilon_0 . k_\alpha} . \cot\left(\frac{\theta}{2}\right)$$

$$\Rightarrow b \propto \cot\left(\frac{\theta}{2}\right)$$

$$\Rightarrow b \propto \frac{1}{k_\alpha}$$

$$\Rightarrow b \propto Z$$

Ex. **Find the angle of scattering for impact parameter to be zero.**

Sol.

$$b = \frac{ze^2}{4\pi\epsilon_0 k_\alpha} . \cot\left(\frac{\theta}{2}\right)$$

$$b = 0 \Rightarrow \cot\left(\frac{\theta}{2}\right) = 0$$

$$\Rightarrow \cot\left(\frac{\theta}{2}\right) = \cos 90 \Rightarrow \frac{\theta}{2} = 90$$

$$\Rightarrow \theta = 180$$

Failures/Drawbacks of Rutherford's model –

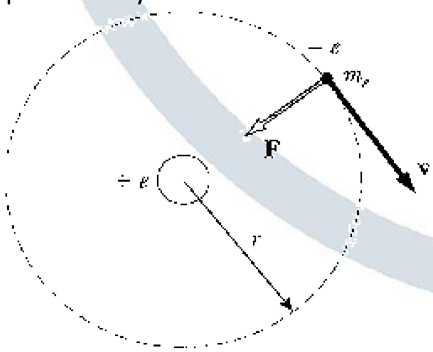
Q1 – Why e^- does not fall in nucleus.

Q2 – EM radiations not emit. Why the spectrum is not continuous.

Bohr's Atomic model (Valid only for atom/ions containing single e^- –

Bohr's postulates –

1. There is a +vely charged nucleus at the centre of atom where of the mass of atom is concentrated and electrons are revolving around nucleus in circular orbits. The necessary centripetal force is been provided by electrostatic force of attraction between +vely charged nucleus and e^-.



$$F_{cp} = F_e$$

$$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0} . \frac{(ze)(e)}{r^2}$$

$$\Rightarrow \frac{mv^2}{r} = \frac{ze^2}{4\pi\epsilon_0 r} \dots\dots\dots\dots\dots (1)$$

2. e^- revolves in those stationary orbits where its angular momentum is integral multiple of $\frac{h}{2\pi}$.

$$mvr = \frac{nh}{2\pi} \dots\dots\dots (2)$$

From 1st postulate,

$$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\epsilon_0}\frac{(Ze)(e)}{r_n^2}$$

$$mv_n^2 = \frac{Ze^2}{4\pi\epsilon_0 r_n} \dots\dots\dots (1)$$

From 2nd postulate,

$$mv_n r_n = \frac{nh}{2\pi} \dots\dots\dots (2)$$

$$\Rightarrow v_n = \frac{nh}{2\pi m r_n}$$

Putting value of v_n from equation (2) in (1)
On solving,

$$m\left[\frac{nh}{2\pi m r_n}\right]^2 = \frac{Ze^2}{4\pi\epsilon_0 r_n}$$

$$\boxed{r_n = \frac{\epsilon_0 h^2}{\pi m e^2}\frac{n^2}{Z}}$$

$$r_n = \frac{8.85 \times 10^{-11} \times (6.6 \times 10^{-34})^2}{3.14 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2} \times \frac{n^2}{Z}$$

$$\boxed{r_n = 0.529 \times \frac{n^2}{Z}\text{Å} \approx 0.53\frac{n^2}{Z}\ \text{Å}}$$

Radius of nth orbit for Bohr model –

$$r_n = \frac{\epsilon_0 h^2}{\pi m e^2}.\frac{n^2}{2} = 0.529.\frac{n^2}{Z}\text{Å}$$

For hydrogen atom $\rightarrow Z = 1$

$$r_{n(H)} = 0.529 \times n^2\text{Å}$$

Diff radius for hydrogen atom –

$$r_H = 0.529 \times n^2\ \text{Å}$$

$$r_1 = 0.529\ \text{Å}$$

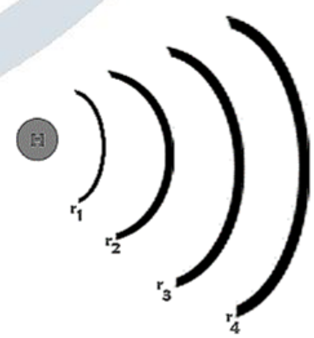
$$r_2 = 2.116\ \text{Å}$$

$$r_3 = 4.761\ \text{Å}$$

$$r_4 = 8.464\ \text{Å}$$

$$n \uparrow \Rightarrow r_n \uparrow$$

$$r_n \propto n^2$$



$$r_n \propto \frac{1}{Z}$$
$$r_2 - r_1 = 2.116 - 0.529 = 1.587 \text{ Å}$$
$$r_3 - r_2 = 4.761 - 2.116 = 2.645 \text{ Å}$$
$$r_4 - r_3 = 8.464 - 4.761 = 3.703 \text{ Å}$$

Ex. **Find radius of e^- in first orbit of Li^{++}.**

Sol.

$$r_n = 0.529 \times \frac{n^2}{Z}$$

For,

$$Li^{++} \rightarrow Z = 3$$
$$\rightarrow n = 1$$
$$r_{1(Li)} = 0.529 \times \frac{(1)^2}{3} = 0.178 \text{ Å}$$

Velocity of electron in n^{th} orbit –

From first postulate,

$$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\epsilon_0} \cdot \frac{(Ze)(e)}{r_n^2}$$
$$\Rightarrow mv_n^2 = \frac{Ze^2}{4\pi\epsilon_0 r_n} \dots\dots\dots\dots\dots (1)$$

From 2^{nd} postulate,

$$mv_n r_n = \frac{nh}{2\pi} \dots\dots\dots (2)$$

Equation (1) dividing (2),

$$\frac{mv_n^2}{mv_n r_n} = \frac{\frac{Ze^2}{4\pi\epsilon_0 r_n}}{\frac{nh}{2\pi}}$$
$$\Rightarrow \frac{v_n}{r_n} = \frac{2\pi Ze^2}{4\pi\epsilon_0 r_n . nh}$$
$$V_n = \frac{e^2}{2\epsilon_0 h} \frac{Z}{n}$$
$$v_n = \frac{(1.6 \times 10^{-19})^2}{2 \times 8.85 \times 10^{-12} \times 6.6 \times 10^{-34}} \times \frac{Z}{n}$$
$$v_n = 2.2 \times 10^6 \times \frac{Z}{n} \text{ m/s}$$
$$V_n \propto Z$$
$$V_n \propto \frac{1}{n}$$

For hydrogen atom – $Z = 1$

$$v_n = 2.2 \times 10^6 \times \frac{1}{n}$$
$$v_1 = 2.2 \times 10^6 \text{ m/s}$$
$$v_2 = 1.1 \times 10^6 \text{ m/s}$$
$$v_3 = 0.7 \times 10^6 \text{ m/s}$$
$$v_4 = 0.5 \times 10^6 \text{ m/s}$$

$$\boxed{v_n = \frac{e^2}{2\epsilon_0 h}.\frac{Z}{n} = \frac{C}{137} \times \frac{Z}{n} \text{ m/s}}$$

Time period of revolution of electron in n^{th} orbit –

$$T_n = \frac{2\pi r_n}{v_n}$$
$$T_n = \frac{2\pi.\frac{\epsilon_0 h^2}{\pi m e^2}.\frac{n^2}{Z}}{\frac{e^2}{2\epsilon_0 h}.\frac{Z}{n}}$$
$$\Rightarrow T_n = \frac{2\pi\epsilon_0 h^2 2\epsilon_0 h}{\pi m e^2. e^2}.\frac{n^3}{Z^2}$$
$$\Rightarrow T_n = \frac{4\epsilon_0^2 h^3}{m e^4}.\frac{n^3}{Z^2}$$
$$T_n \propto \frac{n^3}{Z^2}$$

4. Frequency of revolution –

$$f = \frac{1}{T}$$
$$\therefore f = \frac{m e^4}{4\epsilon_0^2 h^3}.\frac{Z^2}{n^3}$$

5. Angular momentum in n^{th} orbit –

$$L_n = mvr$$
$$L_n = \frac{nh}{2\pi}$$
$$L_1 = \frac{h}{2\pi}$$
$$L_2 = \frac{2h}{2\pi} = \frac{h}{\pi}$$