Physics

By

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Class: 10+2

Unit: VIII

Topic: Atoms and Nuclei

Unit VIII: Atoms and Nuclei **14 Periods**

Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model, energy levels, hydrogen spectrum.

Composition and size of nucleus, Radioactivity, alpha, beta and gamma particles/rays and their properties; radioactive decay law.

Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

gical order.

2.	(a) Draw and explain experimental set-up for Rutherford's α–scattering experiment. (b) What were observations and conclusions drawn from α– scattering experiment?	8/04
3.	(a) Explain "Impact Parameter" for collision and α - scattering experiment. (b) Derive an expression for "Distance of closest approach."	8/05
4.	For an electron moving around hydrogen nucleus, Find (a) Velocity (b) Electric P.E (c) K. E (d) T. E and its significance.	8/06
5.	(a) Explain "emission spectra" and "absorption spectra". (b) Name various emission spectra series in hydrogen and the region in which they fall.	8/07
6.	(a) Write three postulates of Bohrs model? (b) Discuss Limitations of Bohr's model.	8/08
7.	(a) Derive an expression for Bohr radius. (b) Derive an expression for Energy of an electron in nth orbit.	8/09
8.	(a) Write and explain De-Broglie's formula? (b) How De- Broglie's formula explains Bohr's 2^{nd} postulate?	8/10

Q1. Write atom development events from 1885 to 1930 in chronological order.

Ans: **1885-** J.J Balmer gave an empirical formula for spectral lines of different atoms.

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

Any atomic model was subjected to verification of Balmer formula.

1897- J.J. Thomson experiment on gases. He concluded that all atoms were having same type of negatively charged particle i.e "electrons".

1898- J.J Thomson suggested plum pudding model.

1911- E. Rutherford's students i.e H.Geiger and E. Marsdon performed α - scattering experiment. Rutherford concluded that +ve charge is at centre and nucleus is very small. Electrons revolve around the nucleus i.e "Planetory model" of atom. But Rutherford model could not explain spectra or could not explain Balmer's empirical formula.

1913- Niel Bohr proposed the model, giving complete address of each electron and it's energy. However, he could not explain stable orbit of an accelerated charged particle i.e electron.

Niel Bohr derived a formula which matched with empirical formula given by J.J. Balmer. It is because of the same he explained spectra and his model was accepted.

1923- L. De Broglie gave formula, $\lambda = \frac{h}{mv}$. He explained how an electron waves around the nucleus and remains in stable orbit

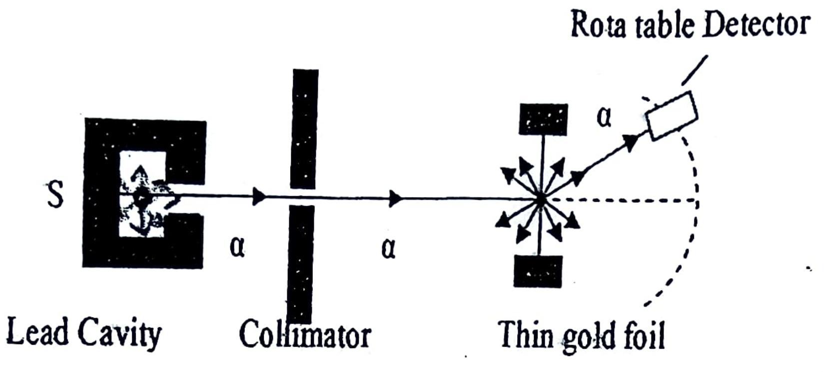
[Ex → Here $2\pi r = 4\lambda$].

+2 / Unit 8A / Q1 Development of Atom Theory

Q2. a) Draw and explain experimental set – up for Rutherford's α-scattering experiment.

b) What were observations and conclusions drawn from α-scattering experiment?

Ans: (a) <u>Experimental set – up</u>



(b) <u>Observations</u>:

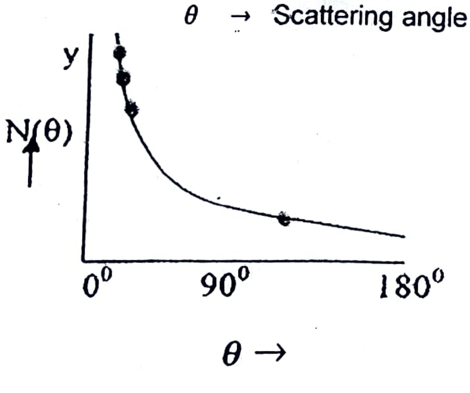
1. Dotted curve is theoretical prediction and Bold dots are practical observations.
2. 0.14% undergo $\theta = 1°$

   1 in 8000 undergo $\theta > 90°$

   1 in 10^6 undergo $\theta \approx 180°$

N(θ) → No. of Scattered particles.

θ → Scattering angle (in degree)



<u>Conclusions</u>:

1. Size of nucleus is 10^{-15} m to 10^{-14} m
2. Total +ve charge is present in very small volume at centre.
3. $r_{nuc} = 10^{-4}\ r_{atom}$

   $V_{nuc} = 10^{-12}\ V_{atom}$ [r → radius, V → volume]

+2 / Unit 8A / Q2 Rutherford's Alpha Scattering Experiment

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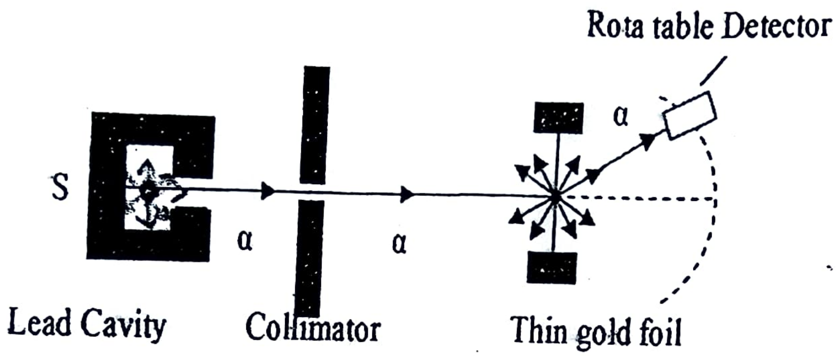

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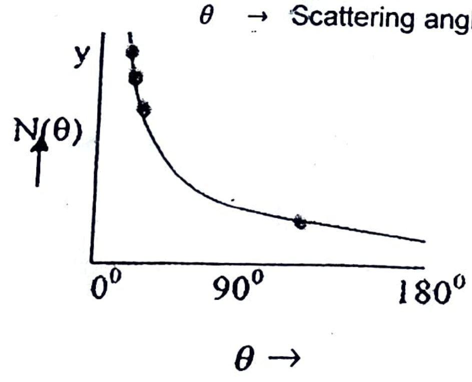

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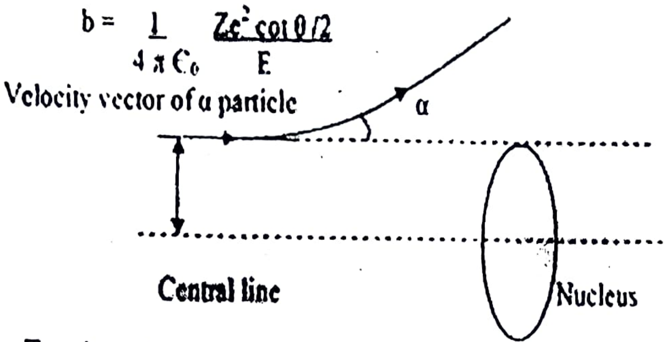
+2 / Unit 8A / Q2 Rutherford's Alpha Scattering Experiment

Q3. a) Explain **"Impact Parameter"** for collision and α- scattering experiment.

b) Derive an expression for "Distance of closest approach."

Ans: (a) **Impact Parameter**: The impact parameter is perpendicular distance of initial velocity of α particles from the centre of nucleus. If b is small, α particle suffers large deflection.

$$b = \frac{1}{4\pi\epsilon_0}\frac{Ze^2 \cot\theta/2}{E}$$



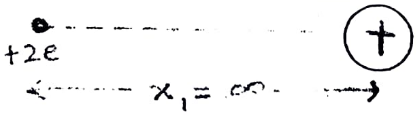
For head on collision, b = 0 and α particle suffers maximum deviation of 180°.

Head on collision

(b) **Distance of closest approach**. A particle moving for head on collision from ∞ distance with velocity u is shown in fig.

$T.E_1 = K.E_1 + P.E_1$

$$= \frac{1}{2}.mu^2 + \frac{q_1 q_2}{4.\pi\epsilon_0.x_1}$$

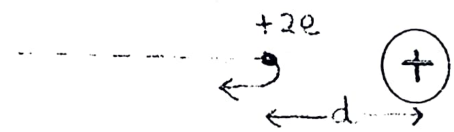


$$T.E_1 = \frac{1}{2}mu^2 + 0 \quad \text{——— (1)}$$

As particle approaches gold nucleus, speed of $\propto$- particle decreases due to force of repulsion. Speed becomes zero at distance d and particle returns.

$T.E_2 = K.E_2 + P.E_2$

$$= 0 + \frac{q_1 q_2}{4.\pi\epsilon_0.d}$$



$$T.E_2 = 0 + \frac{(Ze)(2e)}{4.\pi\,\epsilon_0\,.d} \quad \text{——— (2)}$$

From equation. (1) and (2)

$$\frac{(Ze)(2e)}{4.\pi\,\epsilon_0.d} = \frac{1}{2}.\,mu^2 \quad \Rightarrow \quad d = \frac{(Ze)(2e)}{4\pi\,\epsilon_0\left(\frac{1}{2}.mu^2\right)}$$

+2 / Unit 8A / Q3 Impact Parameter Distance of Closest Approach

$\left[Numerical: Put\ z = 79, \frac{1}{2}\ mu^2 = 7.7\ Me\ V, d = 3\ \times 10^{-14} m.\right]$

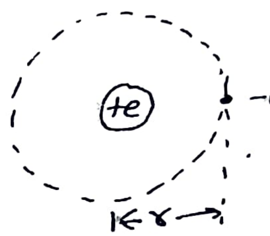
Q4. For an electron moving around hydrogen nucleus, Find

a) Velocity b) Electric P.E

c) K.E d) T.E and its significance.

Ans: (a) **Velocity**:

Electric force provides the necessary centripetal force



$$F_e = F_c$$

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

$$\Rightarrow \boxed{v = \sqrt{\frac{e^2}{4\pi\, \epsilon_0\, r.m}}} \text{ ——— (1)}$$

(b) **E.P.E**

$$\text{E.P.E} = \frac{q_1 q_2}{4\pi\epsilon_0 r} = \frac{(+e)(-e)}{4\pi\epsilon_0 r}$$

$$\boxed{\text{E.P.E} = \frac{-e^2}{4\pi\epsilon_0 r}} \text{ ——— (2)}$$

c) **K.E**

$$\text{K.E} = \frac{1}{2}.m.v^2$$

$$= \frac{1}{2}.m.\left(\frac{e^2}{4.\pi.\epsilon_0.r.m}\right)$$

$$\boxed{\text{K.E} = \frac{1}{2}\left(\frac{e^2}{4.\pi.\epsilon_0.r}\right)} \text{ ——— (3)}$$

+2 / Unit 8A / Q4 Energy of electron moving Around Nucleus

d) **T.E:**

Total Energy, T.E = P.E + K.E

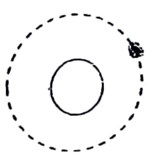
$$= \frac{-e^2}{4\pi.\epsilon_0.r} + \frac{e^2}{2\times 4\pi.\epsilon_0.r}$$

$$\boxed{\text{T.E} = -\frac{e^2}{8.\pi.\epsilon_0.r}} \text{ ——— (4)}$$

T.E is – ve means energy is required to take electron out of this orbit. Such a system is called bound system.

Example:

$$\left\{\begin{matrix} T.E = P.E + K.E \\ -100 = -200 + 100 \end{matrix}\right\}$$



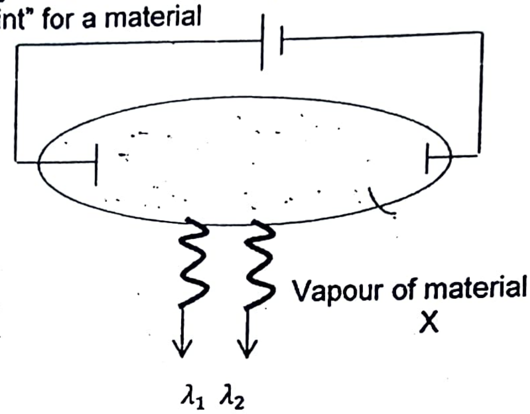
P.E = - 200

K.E = + 100

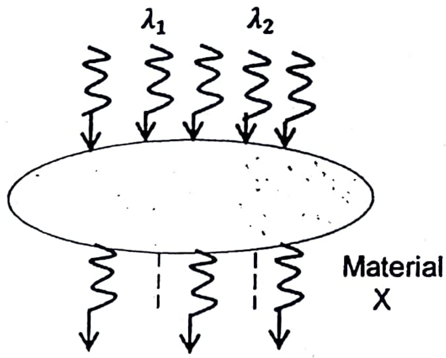
T.E = -100

Q5. (a) Explain "emission spectra" and "absorption spectra".
(b) Name various emission spectra series in hydrogen and the region in which they fall.

Ans: (a) **Emission spectra**: When a low pressure gas is excited by electric discharge, certain wavelengths are emitted such a spectra is termed as emission spectra. Here λ_1 and λ_2 are emitted waves. Every material has its unique emission spectra and acts as "fingerprint" for a material



Absorption spectra: When continuous wavelength are passed through vapours of a material (say X), certain wavelengths are absorbed e.g λ_1 and λ_2. Such a spectra is called absorption spectra.



(b) **Lyman Series**: $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$ $n = 2,3,4$-----------

Where R is Rydberg constant value $\simeq 10^7\ m^{-1}$.
Wavelength of this series fall in "ultraviolet".

Balmer Series: $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ $n = 3,4,5$ -----------

First series found by J.J Balmer who gave the above formula. Wavelength of this series fall in "visible".

Paschan Series: $\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$ $n = 4,5,6$ ----------

Wavelength of this series fall in "Infrared".

Bracket Series: $\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$ $n = 5,6,7$ -----------

Wavelength of this series fall in "Infrared".

P- Fund Series: $\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n^2}\right)$ $n = 6,7,8$ -----------

Wavelength of this series fall in "far infrared region close to radio waves.

+2 / Unit 8A / Q5 Spectra
Hydrogen Spectra

Q6. **(a) Write three postulates of Bohrs model?**
(b) Discuss Limitations of Bohr's model.

Ans: 1. Every atom consists of a central core called nucleus in which entire positive charge and almost entire mass of the atom are concentrated. Suitable no of electrons revolve around nucleus in circular orbits. The centripetal force required for revolution is provided by the electrostatic force of attraction between electron and nucleus.

2. Electrons can revolve only in certain discrete non radiating orbits called stationary orbits, for which total angular momentum of revolving electron is integral multiple of $\frac{h}{2\pi}$

$$mvr = \frac{nh}{2\pi}$$

n = 1,2,3 -------- and is called principle quantum number.

3. The radiations of energy occur only when an electron jumps from one orbit to another.

$$hv = E_2 - E_1$$

Limitations of Bohr's model

1. This theory is applicable only to simplest atom like hydrogen, with Z = 1 the theory gives error in case of atoms of other elements for which Z >1

2. The theory does not explain why orbits of electrons are taken as circular, while elliptical orbits are also possible.

3. Bohr's theory does not explain the fine structure of spectral line even in hydrogen atom.

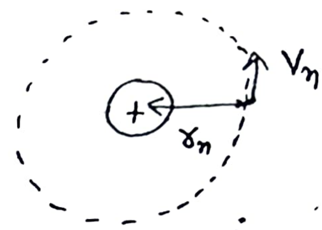
4. Bohr's theory does not give any idea about the relative intensities of spectral lines.

5. Bohr's theory does not take into account the wave properties of electrons.

+2 / Unit 8A / Q6 Bohr's Model Postulates Limitations

Q7. (a) Derive an expression for Bohr radius.
(b) Derive an expression for Energy of an electron in nth orbit.

Ans: (a) **Radius of nth orbit, r_n**



$r_n \rightarrow$ radius of nth orbit.

$v_n \rightarrow$ velocity of nth orbit.

As coulomb force provides the necessary centripetal force

$$\frac{1}{4\pi\epsilon_0} \cdot \frac{e.e}{r_n^2} = m.\frac{Vn^2}{r_n}$$

$$\boxed{V_n = \frac{e}{\sqrt{4.\pi.\epsilon_0.m.r_n}}} \quad \text{——— (1)}$$

As per Bohr's 2nd postulate

$$\boxed{m.V_n.\,r_n = n.\frac{h}{2\pi}} \quad \text{——— (2)}$$

Two equations and two unknown i.e V_n and r_n.

$$\boxed{V_n = \frac{1}{n} \cdot \frac{e^2}{4.\pi.\epsilon_0} \cdot \frac{1}{h/2\pi} \text{ and } r_n = \frac{n^2}{m} \cdot \left(\frac{h}{2\pi}\right)^2 \cdot \frac{4.\pi.\epsilon_0}{e^2}}$$

For n = 1, r_1 is "Bohr radius" $\quad r_1 = \frac{1^2}{m} \cdot \left(\frac{h}{2\pi}\right)^2 \cdot \frac{4.\pi.\epsilon_0}{e^2}$

$$\boxed{r_1 = \frac{h^2.\,\epsilon_0}{\pi.m.e^2}} \quad \text{——— (3)}$$

(b) **Energy**: T.E_n = P.E_n + K. E_n

$$= -\frac{e^2}{4.\pi\,\epsilon_0.r_n} + \frac{1}{2}\left(\frac{e^2}{4.\pi.\epsilon_0.r_n}\right)$$

$$\boxed{T.\,E_n = -\frac{e^2}{8.\pi.\epsilon_0.r_n}} \quad \text{——— (4)}$$

Put value of r_n in equation. (4)

$$T.\,E_n = -\frac{e^2}{8.\pi.\epsilon_0.\frac{n^2}{m}\cdot\left(\frac{h}{2\pi}\right)^2 \cdot \frac{4.\pi.\epsilon_0}{e^2}}$$

$$= -\frac{m.e^4}{8.n^2.\epsilon_0^2.h^2}$$

$$\boxed{T.\,E_n = -\frac{13.6}{n^2}\text{ ev}} \quad \text{——— (5)}$$

+2 / Unit 8A / Q7 Radius Velocity and Total Energy in Nth Orbit

Q8. (a) Write and explain De- Broglie's formula?
(b) How De- Broglie's formula explains Bohr's 2nd postulate?

Ans: (a) If a particle of mass m moves with a velocity v, λ associated with particle is given as

$$\boxed{\lambda = \frac{h}{mv}}$$

Example: For electron moving around nucleus,

V = 1% of 3×10^8 m/s.

$$\lambda = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^6}$$

$$\boxed{\lambda = 2.4\ \text{Å}}$$

(b) Bohr's 2nd postulate as $mvr = \frac{nh}{2\pi}$. (In 1913)

In 1923, De Broglie gave $\lambda = \frac{h}{mv}$

As per equation (1) $mvr = n\left(\frac{h}{2\pi}\right)$

$$2\pi r_n = n\left(\frac{h}{mv}\right)$$

$$2\pi\, r_n = \eta\, \lambda_1$$

For 1st orbit $2\pi r_n = 1\lambda$

2nd $2\pi r_2 = 2\,\lambda$

3rd $2\pi r_3 = 3\,\lambda$

4th $2\pi r_4 = 4\,\lambda$

+2 / Unit 8A / Q8 DeBroglies formula and Bohrs 2nd Postulate