FREE NOTES · NCERT + JEE/NEET LEVEL

Atoms

Thomson and Rutherford models, alpha scattering, closest approach, the Bohr model, formulas for radius and energy, the series of the hydrogen spectrum and the energy level diagram.

01 Thomson model (plum pudding)
02 Rutherford's alpha scattering experiment
03 Closest approach & impact parameter
04 Drawback of Rutherford's model
05 Bohr model (hydrogen-like atoms)
06 Radius, speed & energy
07 Energy level diagram (hydrogen)
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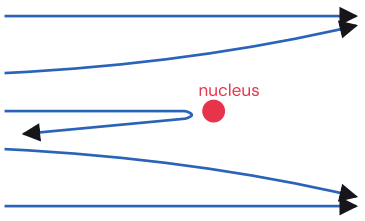
01 Thomson model (plum pudding)

The atom is a sphere of positive charge with electrons embedded in it like raisins in a pudding. The atom is neutral. Rutherford's experiment proved this model wrong.

02 Rutherford's alpha scattering experiment

Geiger and Marsden fired alpha particles (He nuclei, +2e) at a thin gold foil.

Observation	Conclusion
Most passed straight through	The atom is mostly empty
Some were deflected slightly	Positive charge inside
~1 in 8000 bounced back by nearly 180°	All positive charge and mass in a tiny region (nucleus)



A head-on alpha bounces almost straight back

Nuclear size ~10^{-15} m, atomic size ~10^{-10} m (100,000 times larger). Number scattered $N \propto 1/\sin^4(\theta/2)$.

03 Closest approach & impact parameter

DISTANCE OF CLOSEST APPROACH (HEAD-ON)

$$r_0 = (1/4\pi\varepsilon_0) \times 2Ze^2 / K$$

All KE becomes PE. This gives an upper limit on the nuclear size. Larger K ⇒ smaller r_o.

IMPACT PARAMETER B

Perpendicular distance between the alpha's initial direction and the nucleus's centre. $b \propto \cot(\theta/2)$. b = 0 ⇒ θ = 180° (straight back). Larger b ⇒ less deflection.

04 Drawback of Rutherford's model

Model: electrons orbit a tiny positive nucleus (like planets). **Problem:** an orbiting electron is accelerating ⇒ by electromagnetic theory it should radiate energy ⇒ spiral into the nucleus ⇒ atoms would be unstable. Also the spectrum should be continuous, but real spectra are line spectra.

05 Bohr model (hydrogen-like atoms)

1. Electrons can move only in certain **fixed orbits (stationary states)** where they don't radiate energy.
2. In allowed orbits angular momentum is quantised: $mvr = nh/(2\pi)$, n = 1, 2, 3...
3. When an electron jumps between orbits, the energy difference is emitted as a photon: $h\nu = E_i - E_f$.

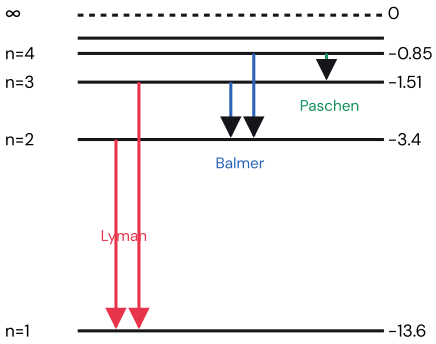
06 Radius, speed & energy

Quantity	Formula (H-like, atomic number Z)	Dependence
Radius	$r_n = 0.529\ n^2/Z$ Å	$\propto n^2/Z$
Speed	$v_n = 2.18 \times 10^6\ Z/n$ m/s $(= c/137$ for H, $n = 1)$	$\propto Z/n$
Total energy	$E_n = -13.6\ Z^2/n^2$ eV	$\propto Z^2/n^2$
KE, PE	$KE = -E,\ PE = 2E$	—
Time period	$\propto n^3/Z^2$	—

REMEMBER

- Negative energy ⇒ the electron is bound.
- Ionisation energy (H, ground state) = 13.6 eV. Ground state = n = 1.
- Excitation energy n = 1 to 2: 10.2 eV; 1 to 3: 12.09 eV.
- Bohr radius a_o = 0.529 Å.

07 Energy level diagram (hydrogen)



Energy levels (eV) and transitions

EMITTED WAVELENGTH

$$1/\lambda = R\,Z^2\,(1/n_1^2 - 1/n_2^2)$$

$R = 1.097 \times 10^7\ m^{-1}$ (Rydberg constant). A drop from n_2 to n_1 ($n_2 > n_1$). Falling from level n gives n(n − 1)/2 possible lines.

08 Series of the hydrogen spectrum

Series	Final level (n_1)	Region
Lyman	1	Ultraviolet
Balmer	2	Visible (some near UV)
Paschen	3	Infrared
Brackett	4	Infrared
Pfund	5	Far infrared

SERIES LIMIT & FIRST LINE

The **shortest λ** of a series (series limit): $n_2 = \infty$. The **longest λ** (first line): $n_2 = n_1 + 1$. Lyman's shortest ≈ 91.2 nm; Balmer's first line (H_α, red) ≈ 656 nm.

09 Bohr's 2nd postulate from de Broglie

The electron must fit around the orbit as a standing wave: the orbit's length = a whole number of wavelengths.

$2\pi r_n = n\lambda = nh/(mv) \Rightarrow mvr = nh/2\pi$ ✓

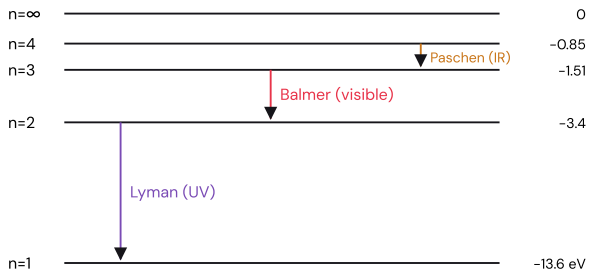
LIMITATIONS OF THE BOHR MODEL

- Works only for one-electron atoms (H, He^{+}, Li^{2+}).
- Doesn't explain line intensities or fine structure.
- A mix of classical and quantum ideas, not a complete theory.

10 JEE Extra + Tricks

JEE LEVEL

- Bohr model: $r_n = 0.529\ n^2/Z$ Å; $v_n = 2.18 \times 10^6\ Z/n$ m/s; $E_n = -13.6\ Z^2/n^2$ eV.
- KE = −E, PE = 2E (PE = −2KE). Ionisation energy of H = 13.6 eV; first excitation = 10.2 eV.
- Number of spectral lines from level n to ground = $n(n-1)/2$.
- Rydberg: $1/\lambda = RZ^2(1/n_1^2 - 1/n_2^2)$, $R \approx 1.097 \times 10^7\ m^{-1}$.
- Series: Lyman ($n_1 = 1$, UV), Balmer (2, visible), Paschen (3), Brackett (4), Pfund (5) (infrared).



Energy levels of hydrogen

11 Solved numericals

Q1. Radius and energy of the n = 3 orbit of hydrogen?
r = 0.529 × 9 = 4.76 Å. E = −13.6/9 = −1.51 eV. **Ans: 4.76 Å, −1.51 eV**

Q2. Ground state energy of He^+ (Z = 2)?
E = −13.6 × 4 = −54.4 eV. **Ans: −54.4 eV**

Q3. Photon emitted in H for n = 3 → n = 2 (eV and nm)?
ΔE = 3.4 − 1.51 = 1.89 eV. λ = 1240/1.89 ≈ 656 nm (red, Balmer H_α). **Ans: 1.89 eV, 656 nm**

Q4. Shortest wavelength of the Lyman series?
$1/\lambda = R(1 - 0) \Rightarrow \lambda = 1/R \approx 91.2$ nm. **Ans: ≈ 91.2 nm**

Q5. A 5 MeV alpha particle and gold (Z = 79). Closest approach? ($k = 9 \times 10^9$)
$r_o = 9 \times 10^9 \times 2 \times 79 \times (1.6 \times 10^{-19})^2/(5 \times 1.6 \times 10^{-13}) = 9 \times 10^9 \times 158 \times 2.56 \times 10^{-38}/8 \times 10^{-13} \approx 4.5 \times 10^{-14}$ m.
Ans: ≈ 45 fm

Q6. An electron falls from n = 5 to the ground state. How many spectral lines are possible?
5 × 4/2 = 10. **Ans: 10**

12 Common mistakes

- Forgetting the sign of energy (a bound electron's energy is negative).
- Thinking radius is linear in n (it's n^2).
- Using $n_2 = n_1 + 1$ for the series limit (use ∞).
- Thinking Lyman is visible (it's UV; Balmer is visible).
- Applying the Bohr model to multi-electron atoms.

13 Formula sheet

Closest approach	$r_0 = 2kZe^2/K$
Angular momentum	$mvr = nh/2\pi$
Radius	$r_n = 0.529\ n^2/Z$ Å
Speed	$v_n = 2.18 \times 10^6\ Z/n$ m/s
Energy	$E_n = -13.6\ Z^2/n^2$ eV
KE, PE	$KE = -E,\ PE = 2E$
Photon	$h\nu = E_i - E_f$
Rydberg	$1/\lambda = RZ^2(1/n_1^2 - 1/n_2^2)$
Number of lines	$n(n-1)/2$

14 Practice questions

1. Ionisation energy of hydrogen in the ground state?
2. How many times larger is the n = 2 radius than n = 1 in hydrogen?
3. In which region is the Balmer series?
4. In some state KE = 3.4 eV. Total energy and PE?

ANSWERS

1) 13.6 eV · 2) 4 times · 3) Visible · 4) E = -3.4 eV, PE = -6.8 eV

15 Quick revision: 5 minutes before the exam

RUTHERFORD

- Most pass straight ⇒ mostly empty atom.
- 180° rebound ⇒ tiny heavy nucleus.
- $r_o = 2kZe^2/K$.

BOHR

- $mvr = nh/2\pi$.
- $r \propto n^2/Z$, $v \propto Z/n$, $E \propto -Z^2/n^2$.
- $E_1 = -13.6$ eV; KE = −E, PE = 2E.

SPECTRUM

- Lyman UV, Balmer visible, Paschen IR.
- Limit: $n_2 = \infty$; first line: $n_2 = n_1 + 1$.
- Lines $n(n-1)/2$.

NUMBERS

- $a_o = 0.529$ Å.
- H_α 656 nm; Lyman limit 91.2 nm.

Have a doubt? Ask the AI Doubt Solver at padhaiadda.netlify.app, or take the mock test on this chapter.