FREE NOTES · NCERT + JEE/NEET LEVEL

Structure of Atom

Subatomic particles, Thomson and Rutherford models, electromagnetic radiation, Planck's quantum theory and photoelectric effect, hydrogen spectrum, Bohr's model, dual nature and uncertainty principle, quantum numbers, orbitals and electronic configuration.

01 Subatomic particles & early models
02 Atomic number, mass number, isotopes
03 Electromagnetic radiation & Planck
04 Photoelectric effect
05 Bohr model & hydrogen spectrum
06 Dual nature & uncertainty principle
07 Quantum numbers & orbitals
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01 Subatomic particles & early models

Particle	Discovered by	Charge	Mass
Electron	J.J. Thomson (cathode rays); charge by Millikan (oil drop)	-1.602×10^{-19} C	9.109×10^{-31} kg
Proton	Goldstein (canal rays)	$+1.602 \times 10^{-19}$ C	1.672×10^{-27} kg
Neutron	Chadwick (1932)	0	1.675×10^{-27} kg

e/m of electron = 1.758×10^{11} C/kg. Cathode rays travel in straight lines from cathode to anode and don't depend on the gas or electrode.

- **Thomson model:** plum pudding; positive sphere with electrons embedded. Couldn't explain scattering.
- **Rutherford's α-scattering** (gold foil): most α passed straight (atom is mostly empty), few deflected, ~1 in 20000 bounced back (tiny, dense, positive **nucleus**).
- Drawback: an orbiting electron should radiate energy and spiral into the nucleus; couldn't explain stability or line spectra.

02 Atomic number, mass number, isotopes

- Atomic number Z = protons; mass number A = protons + neutrons. Notation ${}^{A}_{Z}X$.
- **Isotopes:** same Z, different A (^{1}H, ^{2}H, ^{3}H). **Isobars:** same A, different Z (^{14}C, ^{14}N). **Isotones:** same number of neutrons.
- Isoelectronic: same number of electrons (Na^{+}, Mg^{2+}, F^{-}, Ne).

03 Electromagnetic radiation & Planck

$c = \nu\lambda$, wave number $\bar{\nu} = 1/\lambda$

$$E = h\nu = hc/\lambda$$

h = 6.626 × 10^{-34} J s. Energy is emitted or absorbed in packets (**quanta**; for light, **photons**). Black body radiation could only be explained this way.

Spectrum order (increasing λ): γ < X < UV < visible (400–750 nm) < IR < microwave < radio.

04 Photoelectric effect

Light of high enough frequency ejects electrons from a metal surface (e.g. Cs, K).

- No electrons below **threshold frequency ν_o**, however bright the light.
- Kinetic energy of electrons depends on frequency, number of electrons on intensity.
- Ejection is instantaneous.

$$h\nu = h\nu_0 + \tfrac{1}{2}\, m_e v^2$$

$h\nu_o$ = work function W_o. Explained by Einstein using photons. Light has dual nature (wave and particle).

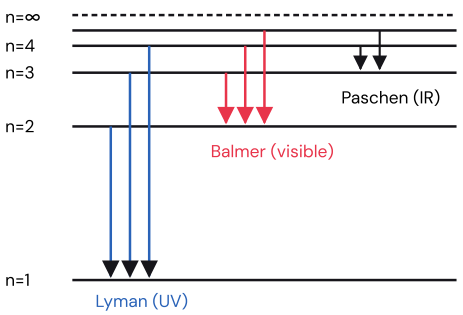
05 Bohr model & hydrogen spectrum

- Electrons move in fixed circular orbits (stationary states) without radiating.
- Energy is absorbed/emitted only on jumping between orbits: ΔE = hν.
- Angular momentum is quantised: $mvr = nh/2\pi$.

$$E_n = -2.18 \times 10^{-18}\,(Z^2/n^2)\ \text{J}$$

$$r_n = 52.9\,(n^2/Z)\ \text{pm}$$

$$\bar{\nu} = 109677\,(1/n_1^2 - 1/n_2^2)\ \text{cm}^{-1}\ \text{(Rydberg)}$$



Hydrogen spectral series

Limitations: fails for multi-electron atoms, can't explain Zeeman/Stark effects, ignores dual nature and uncertainty.

Series	n_1	Region
Lyman	1	UV
Balmer	2	Visible
Paschen	3	IR
Brackett / Pfund	4 / 5	IR

Number of spectral lines from level n to ground: n(n − 1)/2.

06 Dual nature & uncertainty principle

de Broglie: $\lambda = h/mv = h/p$

Heisenberg: $\Delta x \cdot \Delta p \geq h/4\pi$

Every moving particle has a wave nature (seen for electrons in electron microscopes; negligible for large objects). We can't know exact position and momentum together, so fixed orbits are meaningless for electrons ⇒ the idea of **orbitals** (probability regions).

07 Quantum numbers & orbitals

Quantum number	Values	Tells
Principal n	1, 2, 3 …	Shell, size and energy
Azimuthal l	0 to n − 1 (s, p, d, f)	Subshell, shape; angular nodes = l
Magnetic m_l	−l to +l	Orientation; 2l + 1 orbitals
Spin m_s	+½, −½	Spin of electron

- Shapes: s spherical, p dumb-bell (p_x, p_y, p_z), d double dumb-bell (5 orbitals; d_{z^2} different).
- **Nodes:** radial = n − l − 1; angular = l; total = n − 1. 3p: 1 radial, 1 angular.
- Max electrons in shell n = $2n^2$; in a subshell = 2(2l + 1).

08 Filling rules & electronic configuration

- **Aufbau:** fill orbitals in order of increasing energy, by the **(n + l) rule**; if equal, lower n first. Order: 1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p …
- **Pauli exclusion:** no two electrons have all four quantum numbers the same ⇒ max 2 per orbital with opposite spins.
- **Hund's rule:** in degenerate orbitals, pairing starts only after each has one electron (parallel spins).

EXCEPTIONS

Cr: [Ar] $3d^5$ $4s^1$; Cu: [Ar] $3d^{10}$ $4s^1$. Half-filled and fully filled subshells are extra stable (symmetry and exchange energy).

09 JEE Extra + Tricks

JEE LEVEL

- Number of radial nodes = n − l − 1; angular nodes = l; total = n − 1.
- Spin-only magnetic moment $\mu = \sqrt{n(n+2)}$ BM (n = unpaired electrons): 1 → 1.73, 2 → 2.83, 3 → 3.87, 4 → 4.90, 5 → 5.92.
- Exceptions in configuration: Cr = $[Ar]3d^5 4s^1$, Cu = $[Ar]3d^{10}4s^1$ (half-filled/full stability, exchange energy).
- Heisenberg: $\Delta x \cdot \Delta p \geq h/4\pi$; de Broglie $\lambda = h/mv$; for electron accelerated through V: $\lambda = 12.27/\sqrt{V}$ Å.
- Bohr for H-like: $E_n = -13.6\ Z^2/n^2$ eV; $r_n = 0.529\ n^2/Z$ Å; total lines from n to 1 = n(n − 1)/2.
- Orbital energy order (n + l rule): lower n + l first; if equal, lower n first.

10 Solved numericals

Q1. Energy of a photon of λ = 500 nm?

$E = hc/\lambda = (6.626 \times 10^{-34} \times 3 \times 10^{8})/(500 \times 10^{-9})$ = **3.98×10^{-19} J**.

Q2. Energy needed to ionise H from n = 1?

$0 - (-2.18 \times 10^{-18})$ = **2.18×10^{-18} J** per atom (13.6 eV).

Q3. de Broglie λ of a 0.1 kg ball at 10 m/s?

$\lambda = 6.626 \times 10^{-34}/(0.1 \times 10)$ = **6.6×10^{-34} m** (too small to notice).

Q4. Quantum numbers for the last electron of Na?

$3s^1 \Rightarrow n = 3, l = 0, m = 0, s = +½$.

11 Mistakes & practice

- Saying brighter light gives faster photoelectrons (frequency decides KE).
- Filling 3d before 4s (use n + l).
- Writing l = n (maximum is n − 1).
- Confusing radial and angular nodes.

1. How many orbitals in n = 3?
2. Which series of H is visible?
3. Number of radial nodes in 3s?
4. Configuration of Cu?
5. Which particle has the largest de Broglie λ at the same speed: e^-, p, α?

ANSWERS

1) 9 · 2) Balmer · 3) 2 · 4) [Ar] $3d^{10}$ $4s^1$ · 5) Electron (least mass)

12 Quick revision: 5 minutes before the exam

MODELS

- Rutherford: nucleus, empty space.
- Bohr: $E_n = -13.6\ Z^2/n^2$ eV.
- $r_n = 52.9\ n^2/Z$ pm.

LIGHT

- $E = h\nu = hc/\lambda$.
- $h\nu = W_o + KE$.
- Lyman UV, Balmer visible.

QUANTUM

- $\lambda = h/mv$.
- $\Delta x\ \Delta p \geq h/4\pi$.
- n, l (0…n−1), m (−l…+l), s (±½).

FILLING

- Aufbau (n + l), Pauli, Hund.
- Cr $3d^5 4s^1$, Cu $3d^{10} 4s^1$.
- Nodes: n − l − 1 radial, l angular.

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