LOGIC BLOOM · CHEMISTRY · CLASS 11

Structure of the Atom

Complete JEE Main & Advanced Notes — 20 Topics, Traps & Edge Cases

Understand through games · Score through practice

This is not a re-typed NCERT chapter. It is a **strategy document**: every topic carries the core theory you need, the **exact traps** JEE setters build around it, the **Advanced-only edge cases** that separate a 99-percentiler from a topper, and a few **out-of-the-box angles** you will not find in a standard textbook. Each topic links to its Logic Bloom game so you can *feel* the experiment before you memorise the result.

HOW TO USE THESE NOTES

Read the theory → open the 🎮 game and run the experiment yourself → return and attack the trap box → then drill the topic with the ✏️ Playground practice link before moving on. The **blue boxes** are Advanced-only; if you are targeting Mains alone, you can skim them, but reading them costs nothing and frequently rescues a tricky Main question too.

THE 20 TOPICS

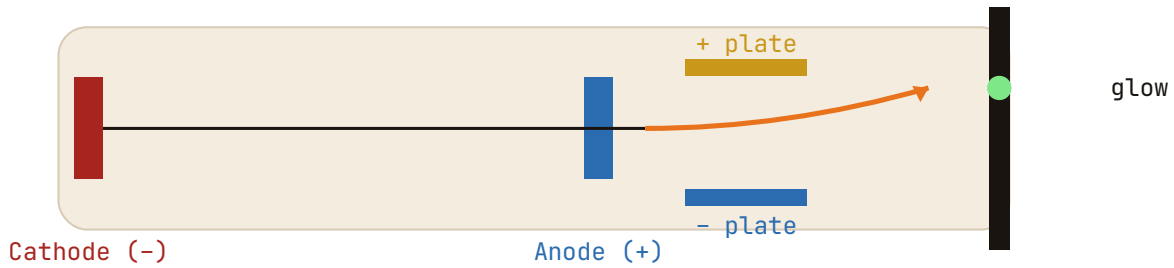
1. Discovery of the Electron
2. e/m_e Ratio & Charge on Electron
3. Protons & Neutrons
4. Thomson Model
5. Rutherford Scattering
6. Z, A, Isotopes & Isobars
7. Drawbacks of Rutherford
8. EM Radiation & Spectrum
9. Planck's Quantum Theory
10. Photoelectric Effect
11. Atomic Spectra of Hydrogen
12. Bohr's Model
13. Bohr Limits & de Broglie
14. Heisenberg Uncertainty
15. Quantum Mechanical Model
16. Quantum Numbers
17. Shapes of Orbitals
18. Orbital Energies & (n+l) Rule
19. Aufbau, Pauli & Hund
20. Electronic Configuration

T01

Discovery of the Electron — Cathode Rays

In a sealed glass tube with two electrodes, pump the gas down to ~0.01 mmHg and apply ~10 kV. A stream flows from the **cathode (–) to the anode (+)**: the cathode rays. The decisive experiments showed they (i) travel in straight lines, (ii) cast sharp shadows, (iii) turn a paddle-wheel (they carry momentum → they are *matter*, not light), and (iv) bend toward the **positive** plate in an electric field (→ negatively charged).

The killer observation: the rays are **identical regardless of the cathode metal or the gas**. That universality is what proves the electron is a fundamental building block of *all* matter — not a property of one element.



Cathode-ray tube. Straight-line travel becomes a curve toward the positive plate under a transverse field — the signature of a negatively-charged particle.

⚠ TRAP — THE ONE SETTERS LOVE

Cathode rays are **not** electromagnetic waves. Light cannot be deflected by an electric or magnetic field; cathode rays are. Any option calling them "EM radiation" or "a form of light" is wrong. Equally, **canal/anode rays depend on the gas, cathode rays do not** — examiners swap these two properties in MCQs constantly.

◆ OUT OF THE BOX

The paddle-wheel result is the historically underrated proof. A wave can carry energy but a *spinning* paddle-wheel needs **momentum transfer by particles with mass**. This is the same logical move Compton later used for photons — momentum is the deciding currency. Carry this intuition forward; it reappears in the photoelectric effect (T10).

🎮 **RUN THE EXPERIMENT — LOGIC BLOOM PLAYGROUND**

Fire the cathode beam yourself, flip the field polarity, and watch the deflection reverse. The "feel" of charge-vs-field locks this in far better than re-reading. → **Open the T01 game (Free to start)**

✏️ **PRACTICE THIS TOPIC — PLAYGROUND**

Run the T01 BrainGym set in the Playground: NCERT in-line questions plus PYQs on cathode rays, discharge tubes & the discovery of the electron, filterable by difficulty. → **Practice T01 in the app (Free to start)**

T02

Charge-to-Mass Ratio & the Charge on the Electron

Thomson (1897) crossed an electric field and a magnetic field at right angles inside the tube. Tune them until the beam goes *straight*: the electric and magnetic forces cancel, so eE = evB ⇒ v = E/B. Then switch off B and measure how far the beam deflects under E alone — that gives the ratio **$e/m_e = 1.758 \times 10^{11}$ C/kg**.

Millikan's oil-drop experiment later pinned the charge itself. Charged oil droplets are suspended by balancing gravity against an upward electric force; the charge always comes out as an **integer multiple of e** (q = n·e) — charge is *quantised*. With **$e = 1.602 \times 10^{-19}$ C** and Thomson's ratio, the mass falls out: **$m_e = 9.109 \times 10^{-31}$ kg**.

```
v = E / B (velocity selector)
e/mₑ = 1.758 × 10¹¹ C kg⁻¹ · e = 1.602 × 10⁻¹⁹ C · mₑ = 9.109 × 10⁻³¹ kg
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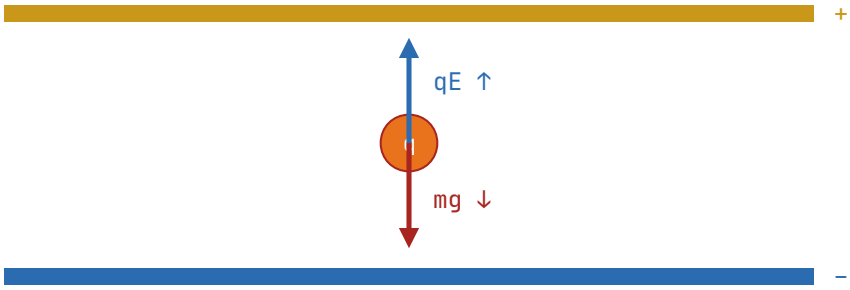
Millikan oil drop — force balance



Suspended ⇒ qE = mg ⇒ q = mg/E, always an integer × e

When the droplet floats, electrical force balances weight; varying voltage reveals that q only ever changes in steps of e.

⚠ TRAP

The ratio **e/mₑ alone never gives the charge** — you need an independent measurement of either e or mₑ. A favourite distractor: "Thomson measured the charge of the electron." He did *not*; he measured the *ratio*. Millikan measured the charge.

▲ ADVANCED EDGE CASE

For a charged particle in crossed fields, the velocity selector passes *only one speed*, v = E/B, regardless of charge or mass. This is why mass spectrometers put a velocity selector *before* the analyser. In Advanced, expect a combined problem: a velocity selector feeds a magnetic analyser where r = mv/(qB) — two stages, two equations.

◆ OUT OF THE BOX

Quantisation of charge (Millikan) is the *first* quantisation you meet in this chapter — before energy (Planck), before angular momentum (Bohr). Notice the pattern the whole chapter is built on: **nature comes in indivisible packets**. Charge → energy → angular momentum → spin. Spotting this thread makes the later topics feel inevitable rather than arbitrary.

🎮 RUN THE EXPERIMENT — T02 GAME

Balance the oil drop yourself by dialling the voltage; the app reveals the charge steps. → **Open the T02 game (Free to start)**

✏ PRACTICE THIS TOPIC — PLAYGROUND

Run the T02 BrainGym set in the Playground: NCERT in-line questions plus PYQs on e/mₑ, Millikan's oil drop & charge quantisation, filterable by difficulty. → **Practice T02 in the app (Free to start)**

T03

Discovery of Protons & Neutrons

Canal rays (anode rays), seen through a perforated cathode, are positive. Crucially their charge-to-mass ratio **depends on the gas** — the opposite of cathode rays. With hydrogen the lightest positive particle appears: the **proton**. Rutherford formally produced it in 1919 by knocking it out of nitrogen with α-particles.

$^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$ (proton) · $^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$ (neutron)

Chadwick (1932) bombarded beryllium with α-particles and detected a neutral particle of nearly proton mass — the **neutron**. Its neutrality is exactly why it was found last: no charge means no electric/magnetic deflection to track it by.

PARTICLE	CHARGE (C)	REL. CHARGE	MASS (KG)	MASS (U)
Electron e^-	-1.602×10^{-19}	−1	9.109×10^{-31}	0.00055
Proton p^+	$+1.602\times10^{-19}$	+1	1.673×10^{-27}	1.00728
Neutron n^0	0	0	1.675×10^{-27}	1.00867

⚠ TRAP

The neutron is **heavier than the proton**, not equal. The difference (≈ 1.3 MeV/c^2) is why a free neutron is unstable and β-decays, while a free proton is stable. Also: **protium (^{1}H) has zero neutrons** — the classic "every nucleus contains neutrons" statement is false.

◆ OUT OF THE BOX

Why was the neutron the *last* subatomic particle found despite being half the nucleus? Because every earlier discovery rode on **charge** — deflection in fields, fluorescent spots, oil-drop balancing. The neutron is invisible to all of that. It had to be inferred from *momentum and energy conservation* in a collision (Chadwick's actual argument), not seen directly. Detection method follows the physics of the particle — a theme worth remembering.

🎮 RUN THE EXPERIMENT — T03 GAME

Fire α-particles at beryllium and reconstruct Chadwick's neutral particle from the recoil. → **Open the T03 game (Free to start)**

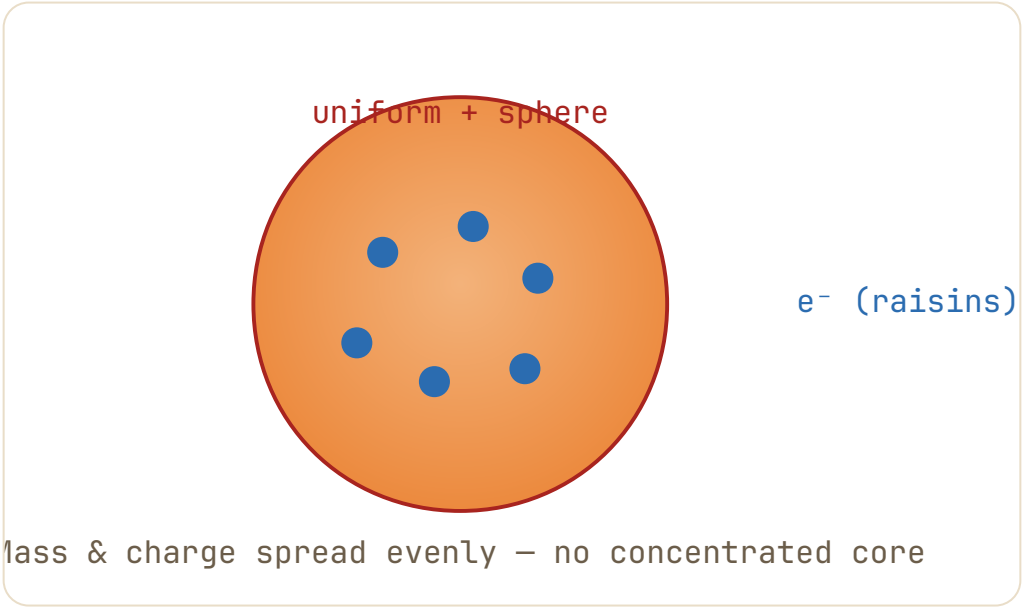
PRACTICE THIS TOPIC — PLAYGROUND

✏️ Run the T03 BrainGym set in the Playground: NCERT in-line questions plus PYQs on protons, neutrons & subatomic particle properties, filterable by difficulty. → **Practice T03 in the app (Free to start)**

T04

Thomson's Model — The Plum Pudding

Thomson (1898) pictured the atom as a uniform sphere (~10^{-10} m) of positive charge with electrons embedded in it like raisins in pudding — also called the watermelon model. It does one job well: it explains **electrical neutrality**. It assumes mass and positive charge are **spread uniformly** across the whole atom.



Plum-pudding model. Its fatal assumption — diffuse positive charge — is exactly what Rutherford's experiment destroys.

⚠ TRAP

Sequence and authorship trip students up. **Thomson came first (1898); Rutherford overturned it (1911).** Thomson's plum-pudding model and his e/m_e measurement are *separate* achievements — exams sometimes attribute the wrong one. Also note: Thomson's model is *not* "wrong about neutrality," only about charge distribution.

▲ ADVANCED EDGE CASE

In the plum-pudding picture a displaced electron feels a Hooke's-law restoring force (the uniform sphere gives F ∝ −r inside it), so it would oscillate at a single frequency and the atom should emit *one* sharp spectral line. Real hydrogen shows *many* lines in series. This quantitative failure — not just the scattering result — is a deeper reason the model dies.

◆ OUT OF THE BOX

The α-scattering verdict hinges on a single number: the model predicts only **tiny** deflections because a diffuse charge can never exert a large force. The instant a single α-particle bounces back >90°, the diffuse-charge hypothesis is dead — one data point falsifies it. This is a clean example of a *crucial experiment*.

🎮 RUN THE EXPERIMENT — T04 GAME

Build the pudding, embed electrons, then predict (wrongly!) what α-particles should do — and see why the model breaks in T05. → **Open the T04 game (Free to start)**

✏️ PRACTICE THIS TOPIC — PLAYGROUND

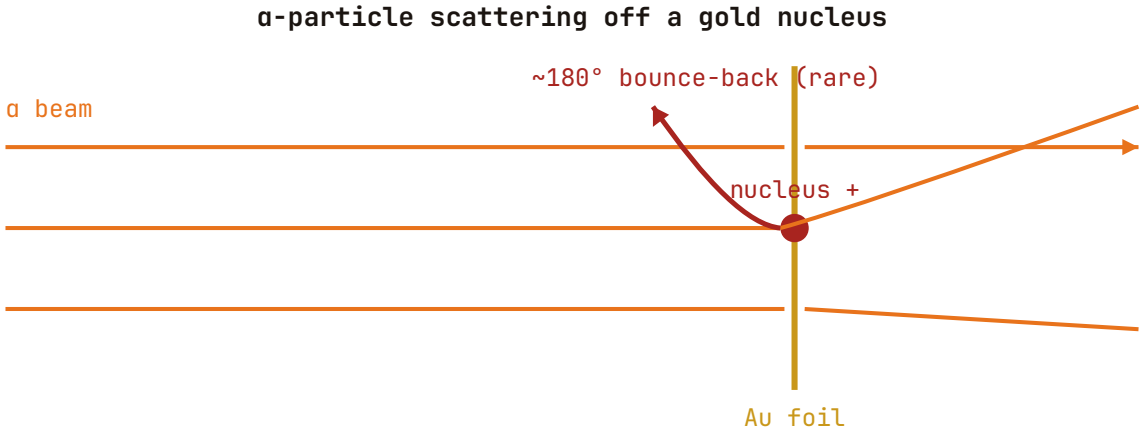
Run the T04 BrainGym set in the Playground: NCERT in-line questions plus PYQs on Thomson's model & its predictions, filterable by difficulty. → **Practice T04 in the app (Free to start)**

T05

Rutherford's Scattering & the Nuclear Model

Geiger and Marsden fired α-particles at ~100 nm gold foil and counted flashes on a movable ZnS screen. Three results, three conclusions:

OBSERVATION	CONCLUSION
Most α pass straight through	Atom is mostly empty space
Some deflect by small angles	Positive charge is concentrated
~1 in 20,000 bounce back >90°	A tiny, dense, positive nucleus exists



The closer an α-particle's path to the nucleus, the larger the Coulomb deflection. A near-head-on approach yields the rare back-scatter.

Scale intuition: atom radius ~10^{-10} m, nucleus ~10^{-15} m. If the nucleus were a cricket ball, the atom would be ~5 km wide. The nucleus holds >99.9% of the mass in ~10^{-15} of the volume.

▲ ADVANCED EDGE CASE — DISTANCE OF CLOSEST APPROACH

At the turning point of a head-on collision, all kinetic energy converts to Coulomb potential energy:

$$\tfrac{1}{2}mv^2 = (1/4\pi\varepsilon_0)\cdot(2e)(Ze)/r_0 \Rightarrow r_0 = (2Ze^2)/(4\pi\varepsilon_0 \cdot \tfrac{1}{2}mv^2)$$

This **r_0 is a standard Advanced numerical** and gives an upper bound on the nuclear radius. Impact parameter b and scattering angle θ relate by $b = (Ze^2/4\pi\varepsilon_0 \cdot \tfrac{1}{2}mv^2)\cdot\cot(\theta/2)$. Memorise the closest-approach formula at minimum.

⚠ TRAP

"Most particles pass through" does **not** mean "the nucleus is small" — it means the atom is mostly **empty**. The *back-scattering* is what proves the nucleus is small and dense. Don't swap the evidence for the conclusion. Rutherford's model says **nothing** about electron orbits or energies — that's Bohr's job (T12).

◆ OUT OF THE BOX

Rutherford famously called the back-scatter "as if you fired a 15-inch shell at tissue paper and it came back." The deeper point: the experiment measures a *probability distribution* of scattering angles, and the angular dependence ($\propto 1/\sin^4(\theta/2)$) was the real proof — not any single particle. This statistical reasoning is the embryo of how all particle physics is done today.

🎮 **RUN THE EXPERIMENT — T05 GAME**

Aim α-particles at the foil, vary the impact parameter, and watch close approaches bounce back. The 1-in-20,000 rarity becomes visceral. → **Open the T05 game (Free to start)**

✏️ **PRACTICE THIS TOPIC — PLAYGROUND**

Run the T05 BrainGym set in the Playground: NCERT in-line questions plus PYQs on Rutherford scattering & closest-approach numericals, filterable by difficulty. → **Practice T05 in the app (Free to start)**

T06

Atomic Number, Mass Number, Isotopes & Isobars

Z = protons (= electrons in a neutral atom) — it defines the *element*. **A** = protons + neutrons = nucleons. Notation: ${}^{A}_{Z}X$, with N = A − Z.

FAMILY	SAME	DIFFERENT	EXAMPLE
Isotopes	Z	A (neutrons)	^{12}C, ^{13}C, ^{14}C
Isobars	A	Z	^{14}C & ^{14}N
Isotones	N (neutrons)	Z, A	^{30}Si, ^{31}P, ^{32}S
Isoelectronic	electrons	nuclei	Na^+, Mg^{2+}, Ne, F^- (10 e^-)

Chemical properties track electron count, so **isotopes are chemically identical** — they differ only in mass-dependent physical properties (density, rate of diffusion, NMR behaviour).

⚠ **TRAP**

In an **ion**, electrons ≠ Z. Fe^{2+} still has Z = 26 protons but only 24 electrons. Students reflexively write "electrons = atomic number" and get every ion question wrong. Also keep **isobars (same A) vs isotopes (same Z)** straight: the mnemonic — isot*o*pes have same pr*o*tons.

◆ OUT OF THE BOX

NCERT lists isotopes and isobars; JEE quietly adds **isotones** (same N) and **isoelectronic species** (same electron count) — and the latter feeds straight into periodic-property questions, because isoelectronic ions are ranked by size using Z_{eff} (more protons → smaller radius: $Na^+ < Ne < F^-$). Two chapters connect here; setters exploit that bridge.

WORKED — ISOELECTRONIC SIZING

Order by radius: O^{2-}, F^-, Na^+, Mg^{2+} (all 10 electrons).

Same electrons, so the one with the *most protons* pulls hardest → smallest. Z: O=8, F=9, Na=11, Mg=12.

Radius: $O^{2-} > F^- > Na^+ > Mg^{2+}$.

🎮 RUN THE EXPERIMENT — T06 GAME

Build nuclei by stacking protons and neutrons, then sort cards into isotope / isobar / isotone bins. → **Open the T06 game (Free to start)**

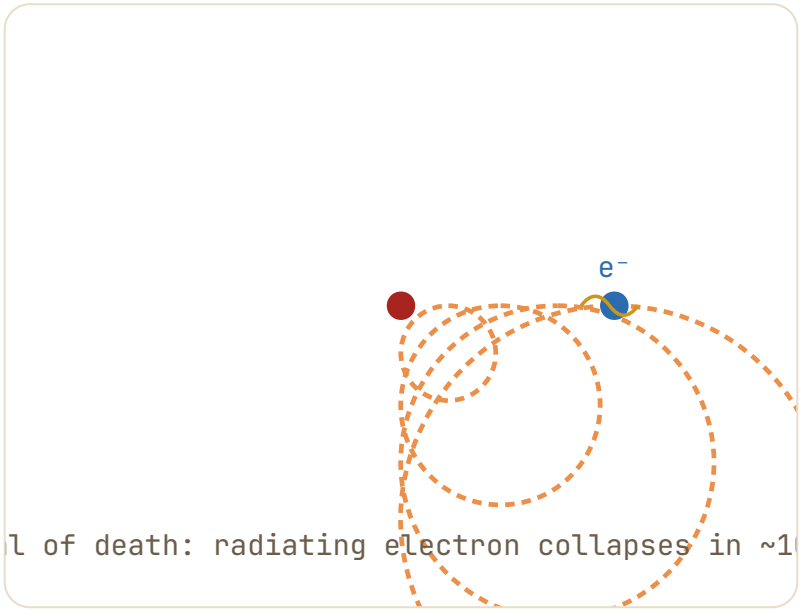
✏️ PRACTICE THIS TOPIC — PLAYGROUND

Run the T06 BrainGym set in the Playground: NCERT in-line questions plus PYQs on Z, A, isotopes, isobars & isoelectronic species, filterable by difficulty. → **Practice T06 in the app (Free to start)**

T07

Drawbacks of the Rutherford Model

Rutherford got the nucleus right but the electrons fatally wrong. By Maxwell's electromagnetism, an electron in a circular orbit is **accelerating** (its direction changes constantly), and an accelerating charge **must radiate** EM energy. Losing energy, the electron should spiral inward and **collapse into the nucleus in ~10^{-8} s**. Atoms are stable for billions of years — contradiction.



Classical prediction: continuous radiation → shrinking orbit → collapse. Observation: stable atoms with discrete (not continuous) spectra.

Two failures, not one: (1) **stability** — the spiral collapse; (2) **spectra** — a spiralling electron would radiate a *continuous* smear of frequencies, but atoms emit sharp *line* spectra. The model is also silent on *how* electrons are arranged.

⚠ TRAP

Keep separate: the nuclear model's **correct** part (a small dense nucleus exists) and its **wrong** part (classical orbiting electrons). Bohr keeps the nucleus and fixes the electrons — he does not discard Rutherford. A common false statement: "Rutherford's model was completely wrong."

◆ OUT OF THE BOX

The line-spectrum failure is actually the *more* productive one. Stability could be patched by hand, but the existence of **sharp, discrete lines** demanded that electron energies themselves be discrete — which is precisely the door Bohr walks through. The drawback that looks like a dead-end is the one that points to the answer. When a theory fails, ask *which* failure is most specific.

🎮 **RUN THE EXPERIMENT — T07 GAME**

Watch the classical electron spiral in real time, then toggle "quantum mode" to see Bohr's fix preview. → **Open the T07 game (Free to start)**

✏️ **PRACTICE THIS TOPIC — PLAYGROUND**

Run the T07 BrainGym set in the Playground: NCERT in-line questions plus PYQs on the drawbacks of Rutherford's model, filterable by difficulty. → **Practice T07 in the app (Free to start)**

T08

Electromagnetic Radiation & the Spectrum

Maxwell: an accelerating charge radiates oscillating **E and B fields, mutually perpendicular and both perpendicular to the direction of travel** (transverse waves). EM waves need **no medium** and travel at **$c = 3.0\times10^8$ m/s** in vacuum.

$c = \nu\cdot\lambda$ · wavenumber $\bar{\nu} = 1/\lambda$ (cm^{-1} or m^{-1}) · $E = h\nu = hc/\lambda$

EM spectrum — increasing frequency →

long λ, low ν, low E — short λ, high ν, high E

Visible: ~400 nm (violet) → ~700 nm (red) — a sliver of the whole

Order by increasing energy: radio < microwave < IR < visible < UV < X-ray < γ. VIBGYOR runs violet (high E) to red (low E).

⚠ TRAP

Wavenumber $\bar{\nu} = 1/\lambda$, not c/λ (that's frequency ν). Units betray which is which: $\bar{\nu}$ in cm^{-1}, ν in Hz. And remember λ and ν are *inversely* related — if a question doubles the wavelength, frequency and photon energy **halve**. Watch the unit on the Rydberg constant: 109677 cm^{-1} gives $\bar{\nu}$, not λ directly.

◆ OUT OF THE BOX

Spectroscopists love $\bar{\nu}$ (cm^{-1}) because, unlike λ, it is **directly proportional to energy** ($E = hc\bar{\nu}$). So an energy-level diagram and a wavenumber axis are linearly related — a transition twice as energetic sits at twice the wavenumber. This is why the Rydberg formula is written in $\bar{\nu}$: the maths becomes additive. Thinking in wavenumbers makes T11–T12 arithmetic almost trivial.

🎮 **RUN THE EXPERIMENT — T08 GAME**

Slide along the spectrum and watch λ, ν and E update live — the inverse relationship becomes muscle memory. → **Open the T08 game (Free to start)**

PRACTICE THIS TOPIC — PLAYGROUND

✏️ Run the T08 BrainGym set in the Playground: NCERT in-line questions plus PYQs on EM spectrum, c = νλ & wavenumber, filterable by difficulty. → **Practice T08 in the app (Free to start)**

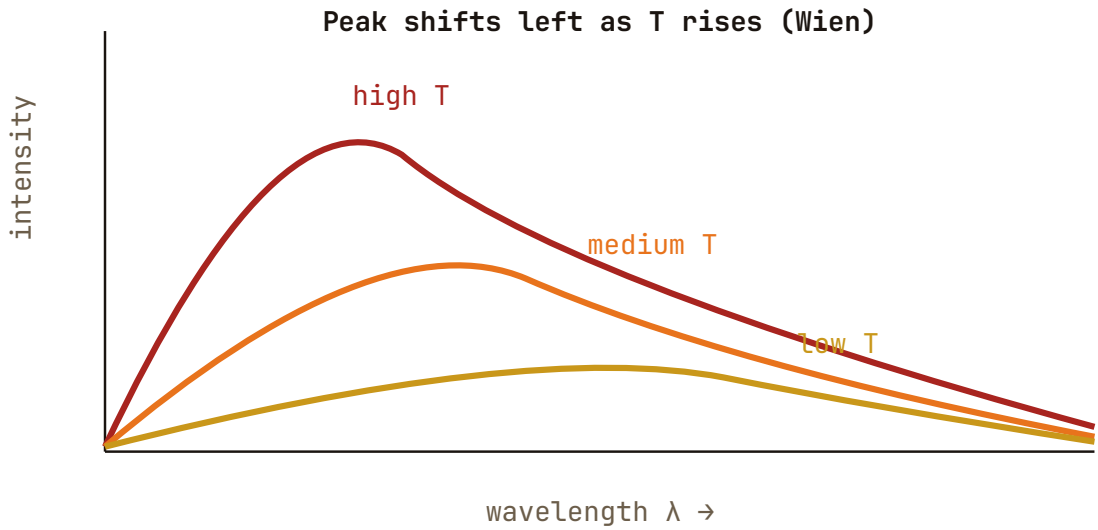
T09

Planck's Quantum Theory & Black-Body Radiation

A heated body emits a spectrum whose **peak shifts to shorter wavelength as T rises** (a poker glows red, then white-hot). Classical wave theory predicted intensity → ∞ at short wavelengths — the absurd **"ultraviolet catastrophe."**

Planck (1900) dissolved the catastrophe with one radical postulate: energy is emitted or absorbed only in discrete **quanta**, E = hν, so the total energy of an oscillator is restricted to **0, hν, 2hν, … nhν**. High-frequency modes need a big quantum hν to get going and are therefore "frozen out" at ordinary temperatures — killing the catastrophe.

$$E = n \cdot h\nu,\ n = 0,1,2,\ldots \cdot h = 6.626\times10^{-34}\ \text{J·s} \cdot \hbar = h/2\pi = 1.055\times10^{-34}\ \text{J·s}$$



Black-body curves. Hotter → peak at shorter λ and greater total area. Classical theory wrongly shot up at short λ; quantisation tames it.

⚠ TRAP

Energy is allowed only at **integer** multiples of hν — never 1.5hν. And don't confuse **h vs ħ = h/2π**: Bohr's angular momentum uses nħ (= nh/2π), Heisenberg uses ħ/2, plain photon energy uses h. Picking the wrong one is a silent factor-of-2π error.

◆ OUT OF THE BOX

Planck himself didn't believe energy was *really* quantised — he called h a "mathematical trick" to fit the curve, and spent years trying to get rid of it. Einstein (T10) took the quantum literally and that's what won the Nobel. Lesson worth absorbing: the person who *derives* an idea and the person who *believes* it can be different — and believing it fully is often the harder, more rewarding step.

🎮 **RUN THE EXPERIMENT — T09 GAME**

Heat the black body, watch the curve peak march leftward, and toggle the classical (broken) prediction to see the catastrophe. → **Open the T09 game (Free to start)**

✏️ **PRACTICE THIS TOPIC — PLAYGROUND**

Run the T09 BrainGym set in the Playground: NCERT in-line questions plus PYQs on Planck's quanta & photon-energy calculations, filterable by difficulty. → **Practice T09 in the app (Free to start)**

T10

The Photoelectric Effect

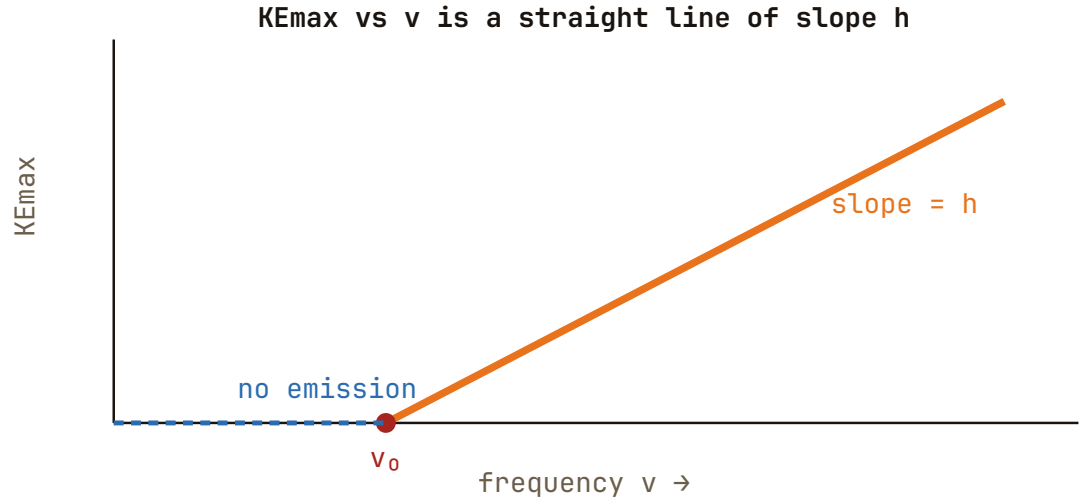
Shine light on certain metals (K, Rb, Cs) and electrons fly out. Four observations break classical wave theory:

- **No time lag** — emission is instantaneous, even at low intensity.
- Electron **count ∝ intensity** (brightness).
- Below a **threshold frequency ν_0**, *no* electrons — no matter how bright.
- Electron **KE ∝ frequency**, independent of intensity.

Einstein (1905): light is a stream of photons, each carrying hν. One photon ejects one electron. Energy bookkeeping:

$h\nu = W_0 + \frac{1}{2}m_e v^2_{max}$ where $W_0 = h\nu_0$ (work function)

$KE_{max} = h\nu - h\nu_0 = h(\nu - \nu_0) \cdot eV_0 = KE_{max}$ (stopping potential)



The KEmax–vs–ν graph is linear: ***slope = h (same for every metal)****, x-intercept = ν_0 (different per metal), and the negative y-intercept magnitude = W_0.*

▲ ADVANCED EDGE CASE — THE GRAPH IS THE GOLDMINE

Advanced rarely asks "what is the photoelectric effect." It asks you to **read graphs**:

- KE_{max} vs ν → slope gives **h** (universal), intercept gives ν_0.
- Stopping potential V_0 vs ν → slope = **h/e**.
- Photocurrent vs intensity (fixed ν) → straight line through origin.
- Photocurrent vs voltage → saturates at high V; V_0 where current hits zero.

Two different metals give **parallel** KE–ν lines (same slope h, different intercepts). Spotting "parallel = same h" instantly kills wrong options.

⚠ TRAP

Intensity does not change electron KE — only the *number* of electrons. Brighter red light still ejects nothing if $\nu < \nu_0$. The maximum KE depends on frequency alone. And don't conflate W_0 with KE_{max}: hν splits *into* W_0 *plus* KE_{max}.

◆ OUT OF THE BOX

The "no time lag" point is the silent classical-killer. A wave spreads its energy over the whole wavefront, so a dim wave should take *minutes to hours* to accumulate enough energy on one electron — yet emission is instant. Only a **localised packet** (photon) delivering all its energy in one hit explains instantaneity. This is the same particle-momentum logic from the cathode-ray paddle-wheel (T01) — the chapter keeps rhyming.

🎮 RUN THE EXPERIMENT — T10 GAME

Crank frequency and intensity independently and watch electrons (or nothing) fly. The ν_0 threshold "click" is unforgettable once you've felt it. → **Open the T10 game (Free to start)**

✏️ PRACTICE THIS TOPIC — PLAYGROUND

Run the T10 BrainGym set in the Playground: NCERT in-line questions plus PYQs on photoelectric numericals & graph-reading (slope = h), filterable by difficulty. → **Practice T10 in the app (Free to start)**

T11

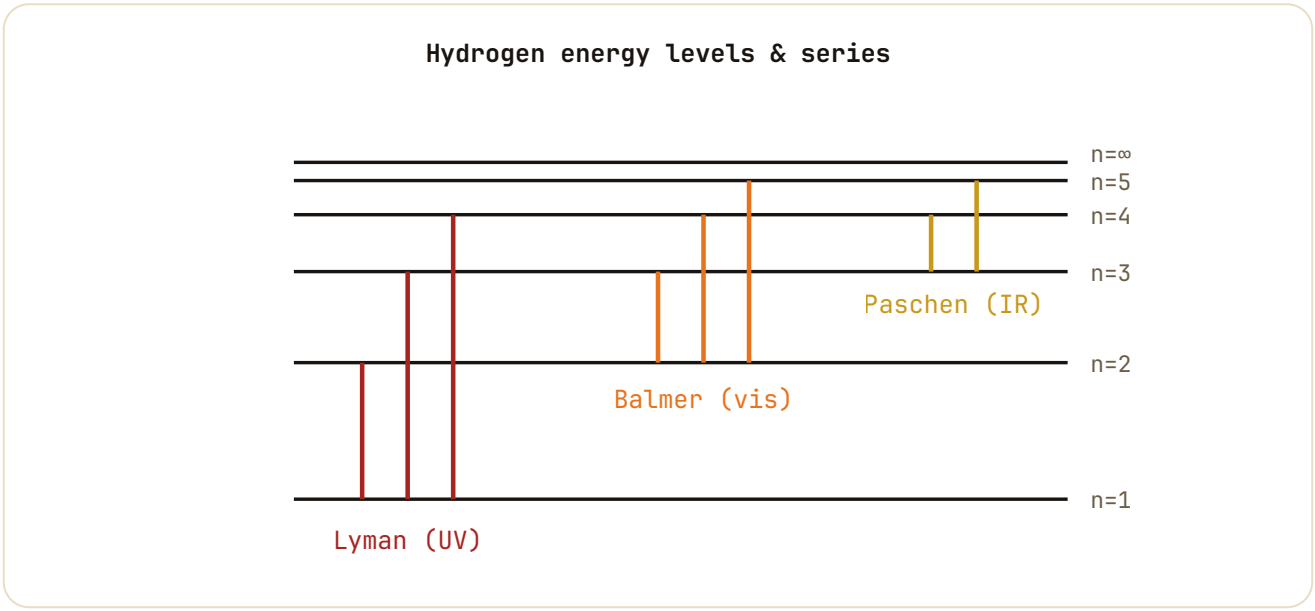
Atomic Spectra & the Line Spectrum of Hydrogen

White light through a prism gives a **continuous** spectrum. But an excited gas emits only **discrete lines** — a fingerprint unique to each element. **Emission** = bright lines on dark; **absorption** = dark lines on bright at the *same* wavelengths (a photographic negative).

For hydrogen, every line obeys the **Rydberg formula**:

$$\bar{\nu} = 1/\lambda = R_H \left(1/n_1^2 - 1/n_2^2 \right) \cdot R_H = 109677\ cm^{-1} = 1.097 \times 10^7\ m^{-1} \quad (n_2 > n_1)$$

SERIES	N_1	REGION	LIMITING λ ($N_2 \to \infty$)
Lyman	1	UV	91.2 nm
Balmer	2	Visible	364.6 nm
Paschen	3	IR	820 nm
Brackett	4	IR	1458 nm
Pfund	5	far IR	2279 nm



Each series ends on a fixed lower level n_1. Lyman (→1) is the most energetic (UV); Balmer (→2) lands in the visible.

▲ ADVANCED EDGE CASE — COUNTING LINES

An electron de-exciting from level n to ground can produce up to **n(n−1)/2 distinct spectral lines** (every downward pair). From n=4 that's 6 lines. If a *sample* of many atoms is excited to n, the same count applies. This "how many lines" question is pure Advanced and trivial once you know the formula. Also: **H-alpha** (Balmer, 3→2) sits at **656.3 nm** — worth memorising as an anchor.

⚠ TRAP

Absorption and emission share the *same* wavelengths — students think they differ. They don't; only bright-vs-dark differs. Also: the **series limit** ($n_2 \to \infty$) is the *shortest* wavelength / highest energy of a series, not the longest. And the Rydberg formula in cm^{-1} gives **$\bar{\nu}$, so invert for λ.**

◆ OUT OF THE BOX

Balmer found his formula in 1885 — *28 years before Bohr explained it* — by sheer numerical pattern-fitting, with no physics behind it. The lesson JEE rewards: spectra are **data first, theory second.** If you treat the Rydberg formula as an empirical fitting tool you can deploy instantly, you'll out-speed students waiting to "derive" everything from Bohr. Helium in the Sun (helium = "helios") was discovered in the solar spectrum before it was found on Earth — line spectra are literally how we read the stars.

🎮 RUN THE EXPERIMENT — T11 GAME

Excite hydrogen, watch electrons drop, and collect each emitted line into its series bin. Seeing Balmer land in the visible is the payoff. → Open the T11 game (Free to start)

PRACTICE THIS TOPIC — PLAYGROUND

✏️ Run the T11 BrainGym set in the Playground: NCERT in-line questions plus PYQs on the Rydberg formula, hydrogen series & line-counting, filterable by difficulty. → **Practice T11 in the app (Free to start)**

T12

Bohr's Model for the Hydrogen Atom

Bohr (1913) grafted quantisation onto Rutherford's nucleus. Four postulates: (i) electrons occupy fixed **stationary states** of definite energy and radius; (ii) in a stationary state the electron *doesn't* radiate (rescuing stability); (iii) it emits/absorbs a photon only when **jumping** between states, with $h\nu = E_2 - E_1$; (iv) **angular momentum is quantised: $mvr = nh/2\pi$**.

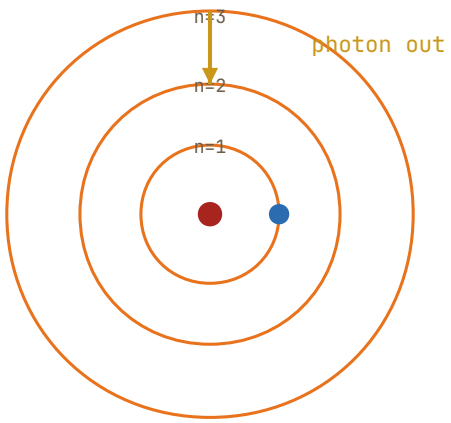
The whole model collapses into a compact formula set. **Memorise these cold** — they generate most of the chapter's numericals:

$r_n = 0.529 \cdot n^2/Z$ Å (Bohr radius $a_0 = 0.529$ Å)

$E_n = -13.6 \cdot Z^2/n^2$ eV $= -2.18\times10^{-18} \cdot Z^2/n^2$ J

$v_n = 2.18\times10^6 \cdot Z/n$ m/s $(= c/137 \cdot Z/n)$

$\Delta E = 13.6\ Z^2\ (1/n_1^2 - 1/n_2^2)$ eV (emission/absorption)



Energy gaps shrink as n grows ($\propto 1/n^2$)

Quantised orbits; radius $\propto n^2$, energy $\propto -1/n^2$. A downward jump emits a photon of exactly the gap energy.

▲ ADVANCED EDGE CASES — HYDROGEN-LIKE IONS

Every formula above carries a **Z**, so He^+ (Z=2), Li^{2+} (Z=3), Be^{3+} (Z=4) are fair game. Key scalings: energy $\propto Z^2$, radius $\propto 1/Z$, velocity $\propto Z$. So He^+ is bound **4× more tightly** than H and its orbit is **half** the size. Also master: **ionisation energy of H = 13.6 eV**; of a hydrogen-like ion = 13.6 Z^2 eV. Time period $T \propto n^3/Z^2$, and current $i = e/T$ — both appear in Advanced.

WORKED — HE^+ IONISATION

Ionisation energy of He^+ from ground state = energy to take electron from n=1 to n=∞.

```
IE = 13.6 × Z² × (1/1² - 0) = 13.6 × 4 = 54.4 eV
```

Four times that of hydrogen — the Z^2 scaling at work.

⚠ TRAP

Energies are **negative**; "more negative = more stable = lower." The ground state (n=1) is the *lowest* energy, not the highest. Bohr applies **only to one-electron systems** (H, He^+, Li^{2+}...) — never to neutral He or beyond. A constant distractor: applying $-13.6/n^2$ to lithium atom.

◆ OUT OF THE BOX

Bohr's quantisation condition $mvr = nh/2\pi$ looks arbitrary — until de Broglie (T13) shows it's just **$2\pi r = n\lambda$**: the orbit must fit a whole number of electron wavelengths, like a standing wave on a circular string. Bohr's "magic rule" is secretly a wave resonance condition. He got the right answer for an almost-right reason; the wave picture is the real "why."

RUN THE EXPERIMENT — T12 GAME

🎮 Drag the electron between orbits and watch the emitted/absorbed photon's colour match the energy gap. → **Open the T12 game (Free to start)**

PRACTICE THIS TOPIC — PLAYGROUND

✏️ Run the T12 BrainGym set in the Playground: NCERT in-line questions plus PYQs on Bohr radius/energy/velocity & hydrogen-like ions, filterable by difficulty. → **Practice T12 in the app (Free to start)**

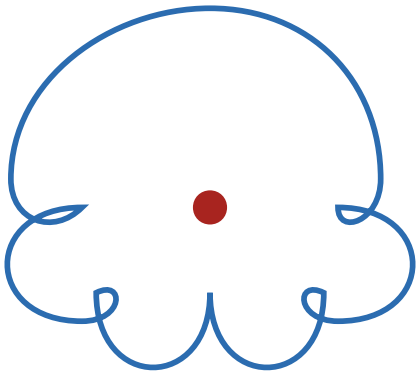
T13

Limits of Bohr's Model & the de Broglie Relation

Bohr nailed hydrogen but failed elsewhere: it can't explain (i) **fine structure** (each "line" is actually closely-spaced lines), (ii) spectra of **multi-electron atoms** — even helium, (iii) the **Zeeman effect** (splitting in a magnetic field) and **Stark effect** (electric field), (iv) **chemical bonding**. Conceptually it violates Heisenberg (it claims a definite orbit) and ignores the electron's wave nature.

de Broglie (1924): if light (a wave) carries momentum like a particle, then matter (particles) should carry a wavelength:

```
λ = h/p = h/mv · for an accelerated charge: λ = h/√(2mqV) · λ_electron(V) ≈ √(150/V) Å
```



de Broglie's standing-wave picture of a Bohr orbit. Only orbits fitting a whole number of wavelengths survive — that is Bohr's quantisation rule.

▲ ADVANCED EDGE CASE

Derive Bohr's rule from de Broglie: a stable orbit needs an integer number of wavelengths around its circumference, **2πr = nλ = n(h/mv)**, which rearranges to **mvr = nh/2π** — Bohr's postulate, now *explained*. Also know: for the same kinetic energy, a heavier particle has a *shorter* wavelength ($\lambda \propto 1/\sqrt{m}$), so a proton's λ is ~1/43 of an electron's at equal KE.

⚠ TRAP

Macroscopic objects *do* have a de Broglie wavelength — it's just absurdly tiny (a cricket ball ≈ 10^{-34} m), hence undetectable. The statement "only microscopic particles have wavelength" is **false**; the correct statement is "only for microscopic particles is it *significant*." Also: λ uses momentum $p = mv$, not velocity alone.

◆ OUT OF THE BOX

de Broglie's PhD thesis was so radical his examiners didn't know whether to pass it — they forwarded it to Einstein, who called it brilliant. Within three years electron diffraction (Davisson–Germer) confirmed it experimentally, and the electron microscope was born from it. The takeaway for problem-solving: when light and matter seem to obey different rules, **look for the symmetric relation** that unifies them (here, p = h/λ works for *both*).

🎮 **RUN THE EXPERIMENT — T13 GAME**

Wrap an electron wave around orbits; only whole-number fits "lock in" and glow — quantisation you can see. → **Open the T13 game (Free to start)**

✏️ **PRACTICE THIS TOPIC — PLAYGROUND**

Run the T13 BrainGym set in the Playground: NCERT in-line questions plus PYQs on de Broglie wavelength problems, filterable by difficulty. → **Practice T13 in the app (Free to start)**

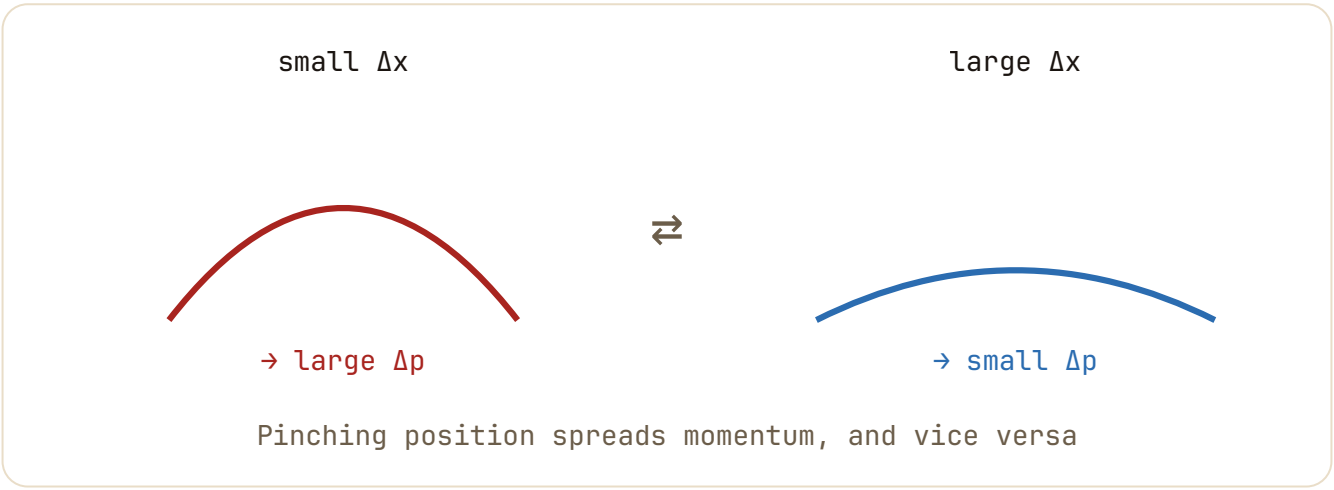
T14

Heisenberg's Uncertainty Principle

You cannot simultaneously know an electron's exact position *and* exact momentum. The more precisely you fix one, the more the other blurs:

$$\Delta x \cdot \Delta p \geq h/4\pi \Leftrightarrow \Delta x \cdot \Delta v \geq h/(4\pi m) \quad (\hbar = h/2\pi \text{ form: } \Delta x \cdot \Delta p \geq \hbar/2)$$

This is **fundamental, not instrumental** — no better microscope can beat it; it's built into the wave nature of matter. It is exactly why Bohr's "definite orbit" is illegal: an orbit specifies position *and* momentum at once.



Squeeze the position distribution and the momentum distribution must widen — the product stays ≥ h/4π.

▲ ADVANCED EDGE CASE — THE "ELECTRON IN THE NUCLEUS" ARGUMENT

A classic Advanced application: assume an electron is confined inside a nucleus ($\Delta x \approx 10^{-15}$ m). Then $\Delta p \geq h/(4\pi \cdot \Delta x)$ gives a momentum so large that the implied kinetic energy is **tens of MeV** — far above nuclear binding energies. Conclusion: **electrons cannot exist inside the nucleus.** This is a favourite "prove it" derivation. The same logic estimates ground-state energies (zero-point energy).

⚠ TRAP

Two form-traps: (1) the bound is **h/4π** (or $\hbar/2$), not h/2π — drop the factor and your answer is off by 2π. (2) The uncertainty has nothing to do with measurement clumsiness; calling it "experimental error" is conceptually wrong and examiners test exactly that distinction in assertion–reason questions.

◆ OUT OF THE BOX

The principle isn't about *disturbing* the electron when you look (that's the older "observer effect" story). It's deeper: position and momentum are **Fourier conjugates** — a wave packet localised in space is necessarily built from a wide spread of momenta, the same maths that says a short musical note has no definite pitch. Position–momentum and time–energy uncertainty are the same theorem wearing different clothes ($\Delta E \cdot \Delta t \geq h/4\pi$ explains why excited states have finite linewidths — connecting back to T11 spectra).

RUN THE EXPERIMENT — T14 GAME

🎮 Squeeze a position slider and watch the momentum spread balloon to keep the product fixed. → **Open the T14 game (Free to start)**

PRACTICE THIS TOPIC — PLAYGROUND

✏️ Run the T14 BrainGym set in the Playground: NCERT in-line questions plus PYQs on Heisenberg uncertainty numericals, filterable by difficulty. → **Practice T14 in the app (Free to start)**

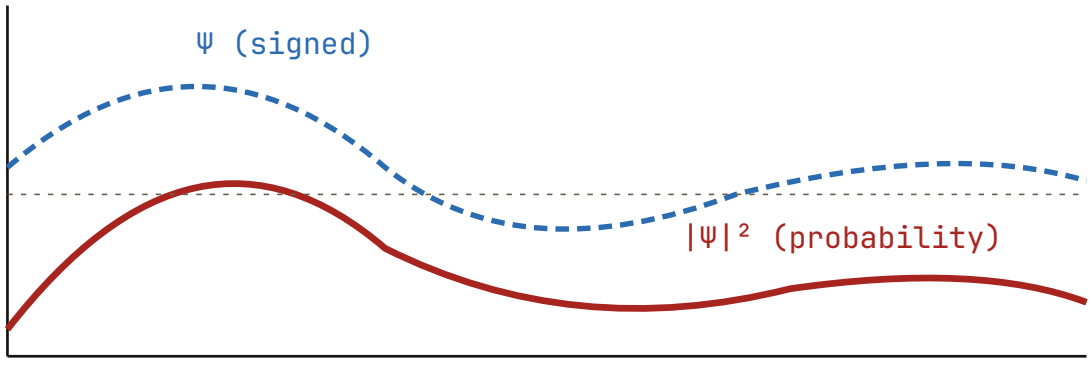
T15

The Quantum Mechanical Model & Schrödinger's Equation

Schrödinger (1926) replaced orbits with **orbitals** — regions of probability. His equation **$\hat{H}\Psi = E\Psi$** yields, for hydrogen, both the allowed energies and the wavefunctions Ψ, each labelled by three quantum numbers (n, l, m_l).

The physical content lives in **$|\Psi|^2$**, the **probability density** of finding the electron at a point. Ψ itself can be negative (it has phase/sign, crucial for bonding), but $|\Psi|^2$ is always ≥ 0 and is what we measure.

```
Ĥψ = Eψ · |ψ|² = probability density · orbital = one-electron wavefunction (max 2 e⁻)
```



Ψ may dip below zero (a node where it changes sign); $|\Psi|^2$ never does. Where $|\Psi|^2$ is large, the electron is likely to be found.

▲ ADVANCED EDGE CASE — RADIAL PROBABILITY VS $|\Psi|^2$

Don't confuse two different curves: $|\Psi|^2$ (probability *density*, peaks at the nucleus for 1s) versus the **radial distribution function $4\pi r^2|\Psi|^2$** (probability of finding the electron in a thin shell at radius r, which is *zero* at the nucleus and peaks at $r = a_0$ for 1s). The "most probable distance" question uses the *second* curve. For 1s hydrogen that peak sits exactly at the Bohr radius — a beautiful link between the two models.

⚠ TRAP

Ψ has **no direct physical meaning**; only $|\Psi|^2$ does. Saying "the wavefunction is the probability" loses marks — it's the *square*. Also, for multi-electron atoms the Schrödinger equation has **no exact solution** (only approximations) — a frequently-tested fact.

◆ OUT OF THE BOX

The **sign** of Ψ — the part that vanishes when you square it — is the single most important thing the quantum model adds for chemistry. Constructive overlap of *same-sign* lobes makes bonding orbitals; opposite signs make antibonding. So the "useless" negative part of Ψ is exactly what builds molecules in your next chapters. The probability picture is for physics; the *phase* is for chemistry.

🎮 RUN THE EXPERIMENT — T15 GAME

Sample the electron cloud point-by-point and watch the $|\Psi|^2$ histogram build the orbital from pure probability. → **Open the T15 game (Free to start)**

✏️ PRACTICE THIS TOPIC — PLAYGROUND

Run the T15 BrainGym set in the Playground: NCERT in-line questions plus PYQs on the quantum model, $|\Psi|^2$ & radial distribution, filterable by difficulty. → **Practice T15 in the app (Free to start)**

T16

The Four Quantum Numbers

QN	SYMBOL	RANGE	TELLS YOU
Principal	n	1, 2, 3 …	shell, size, energy
Azimuthal	l	0 → n−1	subshell, shape (s,p,d,f), orbital ang. momentum
Magnetic	m_l	−l → +l	orientation (2l+1 orbitals)
Spin	m_s	+½ or −½	electron spin direction

Counting rules worth reflex-level recall: orbitals per subshell = **2l+1**; orbitals per shell = **n^2**; max electrons per shell = **$2n^2$**; orbital angular momentum = **$\sqrt{(l(l+1))}\cdot\hbar$**.

▲ ADVANCED EDGE CASE — ANGULAR MOMENTUM VALUES

Advanced asks for *magnitudes*, not just labels: orbital angular momentum = **$\sqrt{(l(l+1))}\cdot(h/2\pi)$**; for a d-electron (l=2) that's $\sqrt{6}\cdot\hbar$. The number of angular nodes = **l**; radial nodes = **n−l−1**; total nodes = **n−1**. Spin angular momentum = $\sqrt{(s(s+1))}\cdot\hbar$ with s=½. These plug straight into "find the orbital" puzzles.

⚠ TRAP

l ranges from 0 to **n−1** — so 2d, 1p, 3f **do not exist**. m_l runs −l to +l *including 0*, giving 2l+1 values. A favourite MCQ lists an impossible set like (n=2, l=2, m_l=0); spotting the illegal l kills it instantly. Spin m_s has only two values, never zero.

◆ OUT OF THE BOX

Spin is *not* the electron physically spinning — a point particle can't. m_s is a purely quantum property with no classical analogue, discovered from the **Stern–Gerlach experiment** (a silver beam splits into exactly two in a magnetic field — the original proof of spatial quantisation, and exactly the kind of "real experiment" worth quoting in subjective answers). Two quantum numbers (n,l) come from the shape of space; m_l from direction; m_s from a hidden internal degree of freedom — four numbers, four independent "questions" about one electron.

🎮 RUN THE EXPERIMENT — T16 GAME

Assemble valid quantum-number sets; illegal combinations (2d, l≥n) are rejected with a buzz. → Open the T16 game (Free to start)

PRACTICE THIS TOPIC — PLAYGROUND

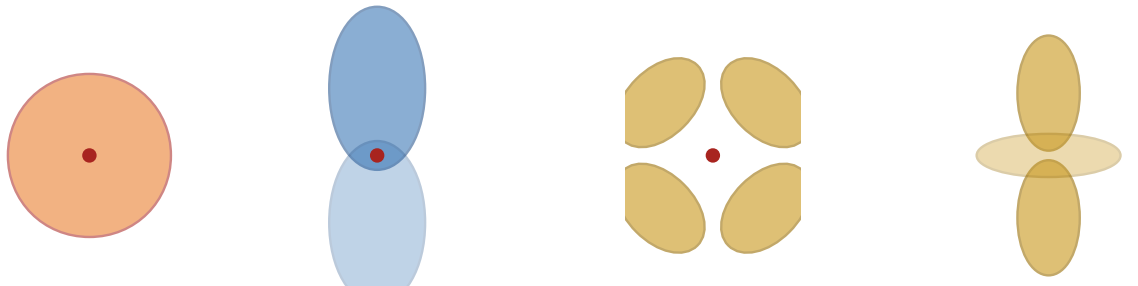
✏️ Run the T16 BrainGym set in the Playground: NCERT in-line questions plus PYQs on quantum-number validity & node-counting, filterable by difficulty. → Practice T16 in the app (Free to start)

T17

Shapes of Atomic Orbitals

s — spherical, electron density nonzero at the nucleus. **p** — dumbbell, two lobes along an axis (p_x, p_y, p_z) with a nodal plane through the nucleus. **d** — five orbitals: four cloverleaf (d_xy, d_yz, d_xz, $d_{x^2-y^2}$) and the distinct d_{z^2} (a dumbbell with a doughnut), all of equal energy.

```
total nodes = n - 1 · angular nodes = l · radial nodes = n - l - 1
```



Shape is set by l. The number of lobes/orientation is angular structure (l); the number of shells within is radial structure (n−l−1).

⚠ TRAP

Don't fuse "shape" with "nodes." **2s has a radial node; 2p has none** (radial nodes = n−l−1 = 0 for 2p) — so 2s is in that sense "more complex." Boundary-surface diagrams enclose ~**90%** probability, not 100% (the cloud technically extends to infinity). The nodal plane of a p orbital passes through the nucleus, which is why p density at the nucleus is exactly zero (unlike s).

◆ OUT OF THE BOX

Why are there exactly five d-orbitals when only four look like clean cloverleaves? Mathematically there are *six* simple combinations, but they're not independent — one is a linear combination of the others, leaving five. The odd-looking **d_{z^2}** is the "leftover" needed to complete the set of five degenerate, mutually orthogonal orbitals. Symmetry, not arbitrary drawing, fixes the count at 2l+1.

🎮 RUN THE EXPERIMENT — T17 GAME

Rotate orbitals in 3D, slice them to reveal nodal planes, and count radial vs angular nodes by eye. → **Open the T17 game (Free to start)**

✏️ PRACTICE THIS TOPIC — PLAYGROUND

Run the T17 BrainGym set in the Playground: NCERT in-line questions plus PYQs on orbital shapes & radial/angular nodes, filterable by difficulty. → **Practice T17 in the app (Free to start)**

T18

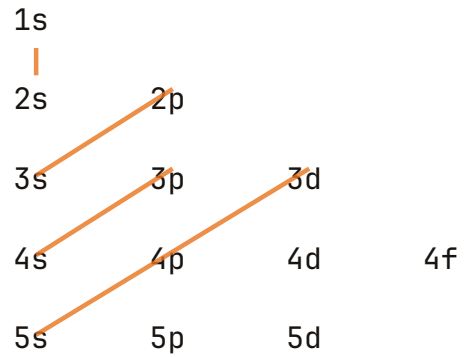
Orbital Energies & the (n + l) Rule

In **hydrogen** energy depends on n alone, so 2s = 2p, 3s = 3p = 3d (degenerate). In **multi-electron atoms**, shielding and penetration split them: within a shell **s < p < d < f**.

```
(n + l) rule: lower (n+l) fills first.
If (n+l) ties, the orbital with lower n fills first.
```

Example: 4s (n+l = 4) fills before 3d (n+l = 5). For 3d vs 4p (both = 5), 3d wins on lower n.

Diagonal (Madelung) filling



Follow arrows top-right → bottom-left

The diagonal rule is just (n+l) made visual. Each arrow sweeps a constant (n+l) family from high-n to low-n... read along arrows to get fill order.

▲ ADVANCED EDGE CASE — PENETRATION & Z_EFF

Why does 4s beat 3d? Because a 4s electron **penetrates** closer to the nucleus (its radial distribution has inner peaks), so it feels a higher effective nuclear charge **Z_eff** and is held more tightly. Penetration order: **s > p > d > f**. But once 3d *is* occupied, it actually sits *below* 4s in energy — which is why ionisation removes the **4s electron first** in transition metals (T20). The (n+l) rule governs *filling order*, not the final energy ordering — a subtlety Advanced loves.

⚠ TRAP

"4s and 3d have the same energy" — false; 4s is lower (fills first), but they're *close*. And the (n+l) rule applies to **multi-electron** atoms; in hydrogen all subshells of a given n are degenerate, so don't apply (n+l) there. Mixing the two regimes is a common conceptual error.

◆ OUT OF THE BOX

The (n+l) rule has *exceptions to its own exceptions* — it predicts filling order with ~90% accuracy, and the famous Cr/Cu anomalies (T19) are where it breaks. The deeper truth is that electrons fill to **minimise total energy**, and (n+l) is only a convenient proxy. When a proxy and the real principle disagree, the real principle wins — which is exactly why Cr is $3d^5 4s^1$, not $3d^4 4s^2$.

🎮 RUN THE EXPERIMENT — T18 GAME

Drag orbitals onto an energy ladder; the app scores you against the true (n+l) order and flags penetration upsets. → **Open the T18 game (Free to start)**

PRACTICE THIS TOPIC — PLAYGROUND

✏️ Run the T18 BrainGym set in the Playground: NCERT in-line questions plus PYQs on the (n+l) rule & orbital-energy ordering, filterable by difficulty. → **Practice T18 in the app (Free to start)**

T19

Filling Orbitals — Aufbau, Pauli & Hund

Aufbau: fill from lowest energy up (the diagonal order). **Pauli exclusion:** no two electrons share all four quantum numbers → max two per orbital, opposite spins. **Hund's rule of maximum multiplicity:** fill degenerate orbitals singly with parallel spins before pairing.

Nitrogen $2p^3$ — Hund's rule:

✓ ↑ ↑ ↑ parallel

× paired too early

Hund: spread electrons out, spins parallel, before any pairing. Pairing early costs exchange-energy stability.

THE CR & CU ANOMALIES — KNOW THESE BY HEART

Cr (Z=24): [Ar] $3d^5$ $4s^1$ (not $3d^4 4s^2$) — half-filled d^5 stability.
Cu (Z=29): [Ar] $3d^{10}$ $4s^1$ (not $3d^9 4s^2$) — fully-filled d^{10} stability.
Driven by (1) symmetric charge distribution and (2) maximum **exchange energy**.

▲ ADVANCED EDGE CASE — EXCHANGE ENERGY IS THE REAL REASON

The popular "half-filled is stable" line is a shorthand. The actual driver is **exchange energy**: every pair of parallel-spin electrons in degenerate orbitals lowers energy by an exchange term. d^5 has the maximum number of parallel pairs (10 exchange pairs), so promoting one 4s electron to complete d^5 pays off. Advanced may ask you to *count exchange pairs* [= n(n−1)/2 for n parallel electrons] to justify the anomaly. This is the rigorous version examiners reward.

⚠ TRAP

Two errors dominate: (1) writing Cr as $3d^4 4s^2$ — wrong, it's $d^5 4s^1$. (2) Pairing in 2p before all three are singly occupied — violates Hund. Also note many *heavier* elements (Nb, Mo, Ru, Rh, Pd, Pt, Au…) have their own anomalies; the simple d^5/d^{10} story doesn't cover all of them, so don't over-generalise in Advanced.

◆ OUT OF THE BOX

Hund's rule has a tangible consequence you can *see*: parallel unpaired spins make an atom **paramagnetic** (attracted to a magnet), and the number of unpaired electrons sets the magnetic moment $\mu = \sqrt{n(n+2)}$ BM. So an abstract filling rule predicts a measurable lab property — the bridge from this chapter to coordination chemistry. When a rule predicts something you can *measure*, it has earned its place.

🎮 **RUN THE EXPERIMENT — T19 GAME**

Drop electrons into orbital boxes; the app enforces Pauli and Hund and rewards spotting the Cr/Cu anomalies. → **Open the T19 game (Free to start)**

✏️ **PRACTICE THIS TOPIC — PLAYGROUND**

Run the T19 BrainGym set in the Playground: NCERT in-line questions plus PYQs on Aufbau, Hund & the Cr/Cu anomalies, filterable by difficulty. → **Practice T19 in the app (Free to start)**

T20

Electronic Configuration of Atoms & Ions

Two notations: full spdf ($1s^2 2s^2 2p^6 3s^1$ for Na) or noble-gas shorthand ([Ne]$3s^1$). **Core** = filled inner shells; **valence** = outermost-shell electrons that do the chemistry.

THE CATION RULE — THE SINGLE MOST-TESTED POINT HERE

When forming a **cation**, remove electrons from the orbital with the **highest n first** — i.e. **4s before 3d**, even though 4s was filled first.

Fe (Z=26): $[Ar]3d^6 4s^2$ → Fe^{2+}: $[Ar]3d^6$ (lose the two 4s, not the 3d).

WORKED — WHY 4S LEAVES FIRST

Once 3d is occupied, the added nuclear screening pushes 4s *above* 3d in energy. The highest-energy occupied electrons are now the 4s pair, so they ionise first.

`Fe → Fe²⁺ : remove 4s² → [Ar]3d⁶ (4 unpaired e⁻)`

`Mn²⁺ : [Ar]3d⁵ — half-filled, extra stable, 5 unpaired e⁻`

▲ ADVANCED EDGE CASE — STABILITY & MAGNETISM OF IONS

Advanced chains this with periodic trends: Fe^{3+} ([Ar]$3d^5$) is more stable than Fe^{2+} ([Ar]$3d^6$) precisely because d^5 is half-filled — explaining why Fe^{3+} salts are common. Magnetic moment $\mu = \sqrt{(n(n+2))}$ BM lets you back-calculate the number of unpaired electrons from a measured moment, then deduce the ion's configuration and oxidation state. This single thread connects T16, T19 and T20 into one Advanced-level question.

⚠ TRAP

Filling order (4s before 3d) and removal order (4s before 3d) **look identical but for opposite reasons** — fill 4s first because it's lower when empty; remove 4s first because it's higher once 3d is full. Students wrongly remove a 3d electron from Fe^{2+}. Also: write the configuration your exam wants — full vs shorthand — both are correct.

◆ OUT OF THE BOX

Electronic configuration *is* the periodic table in disguise: the last-filled subshell places every element into the s-, p-, d- or f-block, and valence configuration alone predicts oxidation states, colour (d–d transitions), and magnetism. If you can write a configuration fluently, you've front-loaded half of inorganic chemistry for the next two years. This is the highest-leverage skill in the chapter — drill it until it's automatic.

RUN THE EXPERIMENT — T20 GAME

🎮 Build neutral atoms then ionise them; the app checks you remove 4s before 3d and flags the half/full-filled stable ions. → **Open the T20 game (Free to start)**

PRACTICE THIS TOPIC — PLAYGROUND

✏️ Run the T20 BrainGym set in the Playground: NCERT in-line questions plus PYQs on electronic configuration, ionisation order & magnetic moment, filterable by difficulty. → **Practice T20 in the app (Free to start)**

★

Exam Strategy — What Actually Scores

HIGHEST-YIELD ZONES (BUILD SPEED HERE)

- **Bohr formulae (T12)** — radius/energy/velocity with Z scaling; hydrogen-like ions. The densest source of numericals.
- **Photoelectric graphs (T10)** — slope = h, intercept = ν_0; parallel lines = same h.
- **Rydberg + line counting (T11)** — n(n−1)/2 lines; series limits.
- **Nodes & quantum numbers (T16–T17)** — radial = n−l−1, angular = l, total = n−1.
- **Configuration + ionisation order (T19–T20)** — Cr/Cu, 4s-before-3d removal, $\mu = \sqrt{n(n+2)}$.

▲ ADVANCED-ONLY MUST-DERIVE LIST

Distance of closest approach (T05) · electron-in-nucleus impossibility via uncertainty (T14) · Bohr quantisation from de Broglie $2\pi r = n\lambda$ (T13) · radial distribution peak = a_0 (T15) · exchange-pair counting for Cr/Cu (T19) · magnetic moment ↔ unpaired electrons ↔ configuration (T20). If you can derive each from scratch, you own this chapter at Advanced level.

⚠ THE RECURRING TRAP FAMILIES (ONE-LINE EACH)

- Cathode rays ≠ EM waves; their properties are gas-independent (canal rays aren't).
- e/m_e alone never gives charge.
- Neutron is heavier than proton; protium has no neutron.
- Intensity changes electron *count*, frequency changes *KE*.
- $\bar{\nu} = 1/\lambda$ (cm^{-1}), not c/λ.
- Uncertainty bound is $h/4\pi$, and it's fundamental, not instrumental.
- $|\Psi|^2$ is physical, Ψ is not; Schrödinger has no exact multi-electron solution.
- $l \le n-1$, so 2d/1p don't exist.
- Cr = $3d^5 4s^1$; remove 4s before 3d when ionising.

NOW PRACTISE THE WHOLE CHAPTER — LOGIC BLOOM APP

🚀 These notes give you the patterns; the app gives you the reps. For full-chapter practice, run Daily Gym (every Structure-of-Atom PYQ in one filterable bank) or test your recall under pressure in a Battleground duel. For topic-wise drilling, use the Playground links above. → **Open Structure of Atom in the app (Free to start)**

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