CN02 — Atomic Structure

📖 Chapter CN02 · NDA Class 11–12 Level 🎯 NDA Level : High Priority

Atomic Structure is one of the most consistently tested topics in NDA Chemistry. Questions appear on atomic models (especially Rutherford and Bohr), subatomic particles, isotopes/isobars/isotones, and electronic configuration. Average students who can write configurations, identify isotopes from Z and A, and recall Bohr's postulates can score reliably from this chapter.

📌 **What to expect in NDA (based on 2022–2025 pattern):**
(1) Comparison of atomic models — Rutherford's nuclear model & its failure; Bohr's postulates;
(2) Subatomic particles — charge, mass, location of e^-, p^+, n^0;
(3) Atomic number (Z), mass number (A), neutrons = A − Z;
(4) Isotopes, isobars, isotones — definition with examples ($^1H/^2H/^3H$; $^{40}Ar/^{40}Ca$; $^{14}C/^{14}N$);
(5) Electronic configuration using shells (K, L, M, N) and $2n^2$ rule;
(6) Valence electrons and valency; Quantum numbers at basic MCQ level.

Topics at a Glance

① Atomic Models	② Subatomic Particles	③ Z, A, Isotopes	④ Electronic Configuration	⑤ Quantum Numbers
Dalton → Thomson → Rutherford → Bohr	*e^-, p^+, n^0 — charge, mass, location*	*Atomic no., mass no., isotopes, isobars, isotones*	*Shell filling, Aufbau, Pauli, Hund's rule*	*n, l, m, s — basic MCQ concepts*

1. Atomic Models — Historical Development

1.1 The Four Models — Dalton to Bohr

Each model corrected the previous one's failures

Our understanding of the atom evolved through a series of experiments over 100 years. NDA tests the key features and failures of each model — particularly Rutherford's gold foil experiment and Bohr's postulates.

1808

Dalton

Solid Sphere Model

- Atom is the smallest indivisible particle
- Atoms of same element are identical
- Atoms combine in fixed whole number ratios
- Atoms cannot be created or destroyed

⚠ Flaw: No subatomic particles; couldn't explain electricity through matter

1897

Thomson

"Plum Pudding" Model

- Atom = sphere of positive charge
- Electrons embedded like plums in pudding
- First to propose subatomic particles (e^-)
- Overall atom is electrically neutral

⚠ Flaw: Could not explain Rutherford's scattering results

1911

Rutherford

Nuclear Model

- Tiny, dense, positive nucleus at centre
- Electrons orbit around nucleus
- Most of atom is empty space
- Based on α-particle (gold foil) experiment

⚠ Flaw: Orbiting e^- should radiate energy → spiral into nucleus (unstable)

1913

Bohr

Planetary / Shell Model

- Electrons move in fixed circular orbits (shells)
- Each orbit has fixed energy — no radiation while in orbit
- Energy emitted/absorbed only when e^- jumps shells
- Explained hydrogen spectrum successfully

⚠ Flaw: Could not explain multi-electron atoms or Zeeman effect

1.2 Rutherford's Gold Foil Experiment

The experiment that revealed the nucleus — most important for NDA

Rutherford bombarded a thin gold foil with a stream of high-energy alpha (α) particles (He^{2+} ions) and observed where they landed on a surrounding fluorescent screen. The results were shocking and overturned Thomson's model completely.

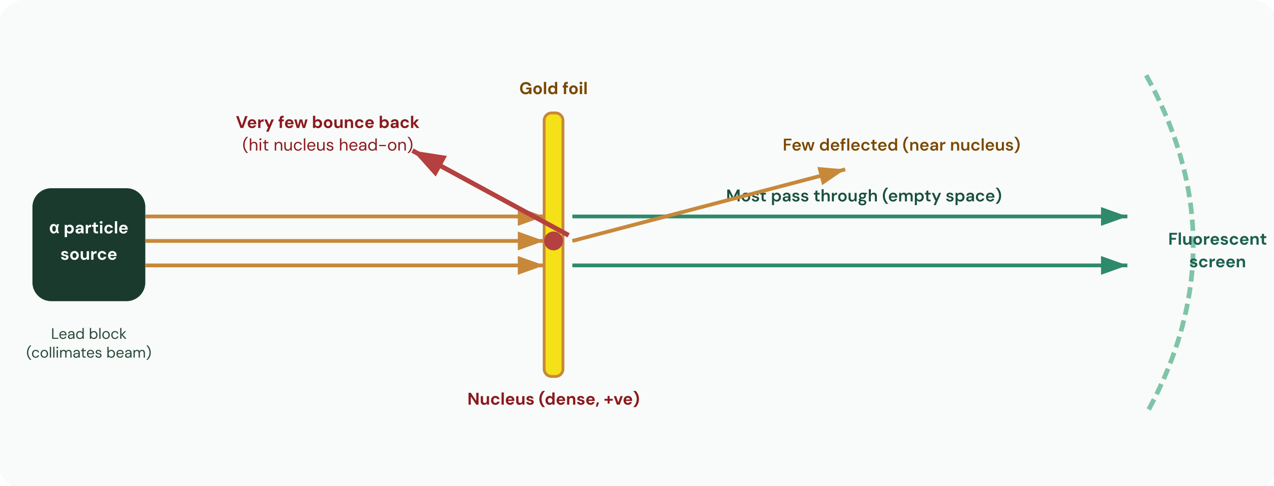

Fig. 1 — Rutherford's Gold Foil (α-scattering) Experiment: most α-particles pass straight through; very few bounce back — proving the nucleus is tiny, dense, and positively charged.

📋 Observations & Conclusions

- **Most α pass straight through** → most of atom is empty space
- **Few deflected at small angles** → positive charge concentrated in tiny region
- **Very few bounce back (1 in 20,000)** → nucleus is extremely dense and small
- Nucleus diameter ≈ 10^{-15} m; atom ≈ 10^{-10} m (100,000× larger)

📌 Bohr's Postulates (NDA must-know)

- Electrons revolve in fixed circular orbits (stationary states) — no radiation
- Each orbit has a fixed energy — orbit closest to nucleus has lowest energy
- Electron jumps to higher orbit by **absorbing** energy (photon in)
- Electron falls to lower orbit by **emitting** energy (photon out) → spectral line
- Angular momentum quantised: $mvr = nh/2\pi$ (n = 1, 2, 3...)

⚛ BOHR'S MODEL — KEY FORMULAE

Energy of nth orbit (Hydrogen atom):

$E_n = -13.6/n^2$ eV (n = 1, 2, 3 ... = principal quantum number)

$E_1 = -13.6$ eV (ground state); $E_2 = -3.4$ eV; $E_3 = -1.51$ eV

Radius of nth orbit: $r_n = 0.529 \times n^2$ Å (for hydrogen)

$r_1 = 0.529$ Å (Bohr radius); $r_2 = 2.116$ Å

Energy of emitted photon when electron jumps from n_2 to n_1 ($n_2 > n_1$):

$\Delta E = E_{n_2} - E_{n_1} = 13.6\,(1/n_1^2 - 1/n_2^2)$ eV

Frequency: $\Delta E = h\nu$ ($h = 6.626 \times 10^{-34}$ J·s; Planck's constant)

Wavelength: $c = \nu\lambda$ ($c = 3 \times 10^{8}$ m/s; speed of light)

NDA shortcut: The Lyman series (UV) ends at n=1, Balmer series (visible) ends at n=2, Paschen series (IR) ends at n=3. The Balmer series is the only one in the visible region.

TOPIC-WISE PYQ

Atomic Models — NDA Pattern Questions

Q1. In Rutherford's α-scattering experiment, most of the α-particles passed through the gold foil without deflection. This shows that:

(a) Gold atoms are very heavy (b) Most of the atom is empty space (c) Nucleus is negatively charged (d) α-particles have high energy

Answer: (b) Most of the atom is empty space
Since the vast majority of α-particles pass through undeflected, they do not encounter any significant obstruction — meaning the atom is mostly empty. Only the rare α-particle that passes very close to the tiny, dense, positive nucleus gets deflected or bounced back. This is the central conclusion of the gold foil experiment.

Q2. According to Bohr's model, when an electron jumps from a higher energy orbit to a lower energy orbit, it:

(a) Absorbs a photon (b) Emits a photon (c) Neither absorbs nor emits (d) Increases its potential energy

Answer: (b) Emits a photon
Higher orbit = higher energy. Falling to lower orbit means the electron loses energy — this energy is released as a photon (a quantum of light): $\Delta E = h\nu$. This is how spectral emission lines are produced. Conversely, going from lower to higher orbit requires absorbing a photon (absorption spectrum).

Q3. Which model of the atom described it as a "plum pudding" or "raisin cake"?

(a) Dalton's (b) Thomson's (c) Rutherford's (d) Bohr's

Answer: (b) Thomson's model

J.J. Thomson (1897) proposed that the atom is a uniform sphere of positive charge with electrons embedded in it — like plums (raisins) in a pudding (cake). He was the first to discover the electron through cathode ray experiments. This model was disproved by Rutherford's 1911 scattering experiment.

2. Subatomic Particles

2.1

Electron, Proton, and Neutron — Properties

Location, charge, and mass — the three facts NDA tests directly

Particle	Symbol	Discovered by	Location	Charge	Mass (amu)	Relative Mass
Electron	e^-	J.J. Thomson (1897)	Orbiting nucleus (shells)	−1 (-1.6×10^{-19} C)	0.000549	1/1836 of proton
Proton	p^+	E. Rutherford (1919)	Inside nucleus	+1 ($+1.6 \times 10^{-19}$ C)	1.0073	≈ 1
Neutron	n^0	James Chadwick (1932)	Inside nucleus	0 (neutral)	1.0087	≈ 1

🔑 **Memory Shortcut: PEN** — Proton is Positive, Electron is (n)Egative, Neutron is Neutral. Proton and Neutron are in the Nucleus; Electrons are Outside (in shells).

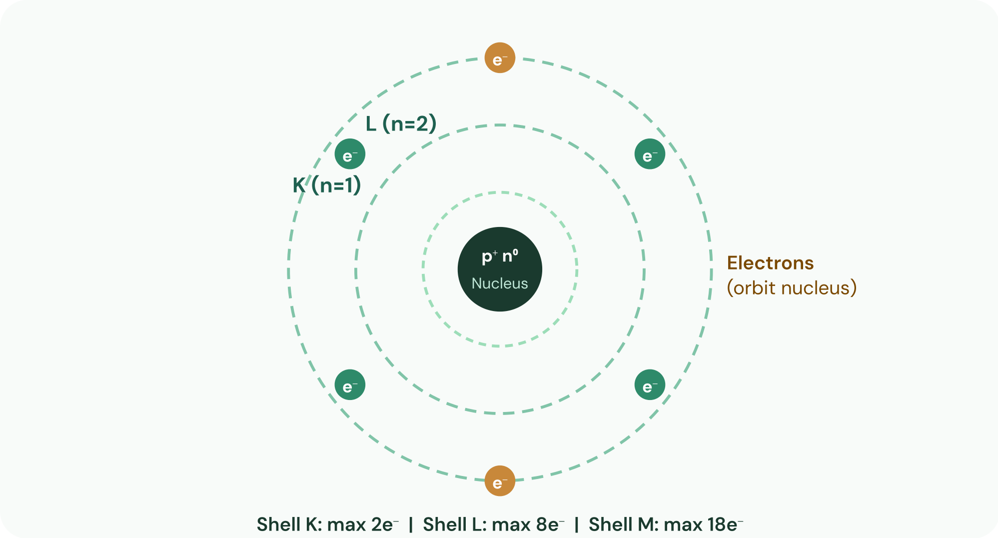

Fig. 2 — Bohr's atomic model showing nucleus (protons + neutrons) and electron shells K, L, M with their maximum electron capacities

⚛ SUBATOMIC PARTICLE FORMULAE

Atomic Number (Z): Z = number of protons in nucleus

= number of electrons (in neutral atom)

Mass Number (A): A = number of protons + number of neutrons

$A = Z + N \rightarrow N \text{ (neutrons)} = A - Z$

Standard notation: $^{A}_{Z}X$ (A on top, Z on bottom, X = element symbol)

Example: $^{23}_{11}Na$ → Z=11 (protons=11), A=23, N=23−11=12 neutrons

Max electrons per shell ($2n^2$ rule):

K shell (n=1): $2 \times 1^2 = 2$

L shell (n=2): $2 \times 2^2 = 8$

M shell (n=3): $2 \times 3^2 = 18$

N shell (n=4): $2 \times 4^2 = 32$

(Note: outermost shell can hold maximum 8; second from last max 18)

The $2n^2$ rule gives the maximum capacity of each shell. In practice, the outermost shell (valence shell) never holds more than 8 electrons (octet rule), and the penultimate shell is limited to 18.

3. Atomic Number, Mass Number & Key Terms

3.1

Isotopes, Isobars, and Isotones

The most commonly confused trio — NDA tests with specific examples

🔬 Isotopes

- **Same Z, different A** (same element, different mass)
- Same number of protons & electrons
- Different number of neutrons
- Same chemical properties, different physical properties
- **Examples:** ^{1}H, ^{2}H (deuterium), ^{3}H (tritium) — hydrogen isotopes
  ^{12}C and ^{14}C (carbon-14 used in dating)
  ^{235}U and ^{238}U (uranium isotopes — nuclear fuel)

🔮 Isobars

- **Same A, different Z** (same mass number, different element)
- Different protons, different electrons
- Different neutrons
- Different chemical properties
- **Examples:** $^{40}_{18}Ar$ and $^{40}_{20}Ca$ (A=40; Ar has 18p, Ca has 20p)
  $^{14}_{6}C$ and $^{14}_{7}N$ (A=14)
  ^{3}H and ^{3}He (A=3)

⚛ Isotones

- **Same number of neutrons, different Z and A**
- N = A − Z is same for all isotones
- Different elements, different masses
- **Examples:** $^{14}_{6}C$ (N=8) and $^{15}_{7}N$ (N=8)
  ^{3}H (N=2) and ^{4}He (N=2)
  ^{39}K (N=20) and ^{40}Ca (N=20)

Term	Same	Different	Example pair	NDA Memory Trick
Isotopes	Z (protons)	A and N (neutrons)	^{12}C and ^{14}C	ISOtopes → same **topic** (same element)
Isobars	A (mass no.)	Z and N	^{40}Ar and ^{40}Ca	ISObars → same **bar** (weight)
Isotones	N (neutrons)	Z and A	^{14}C and ^{15}N	ISOtones → same neut**rone** count

📌 **NDA Special Case — Isoelectronic Species:** Atoms or ions with the **same number of electrons** are called isoelectronic. Example: Na^{+}, Mg^{2+}, Al^{3+}, Ne, F^{-},

O^{2-} all have 10 electrons. This appears in NDA as a statement match or identification question.

TOPIC-WISE PYQ

Atomic Number, Isotopes, Isobars, Isotones — NDA Pattern Questions

Q1. An element $^{27}_{13}Al$ has how many neutrons in its nucleus?

(a) 13 (b) 27 (c) 14 (d) 40

Answer: (c) 14

Neutrons = A − Z = 27 − 13 = **14 neutrons**. Z = 13 = protons = electrons (neutral atom). A = 27 = total nucleons.

Q2. Which of the following pairs represents isobars?

(a) ^{1}H and ^{2}H (b) $^{14}_{6}C$ and $^{14}_{7}N$ (c) $^{14}_{6}C$ and $^{12}_{6}C$ (d) $^{39}_{19}K$ and $^{40}_{20}Ca$

Answer: (b) $^{14}_{6}C$ and $^{14}_{7}N$

Isobars have the same mass number (A) but different atomic numbers (Z). Both ^{14}C and ^{14}N have A = 14 but different Z (6 and 7). Option (a) is isotopes (same Z=1, different A). Option (c) is also isotopes (same Z=6). Option (d) has different A (39 vs 40) — they are isotones (same N=20).

Q3. ^{235}U and ^{238}U are both used in nuclear technology. What is their relationship?

(a) Isobars (b) Isotopes (c) Isotones (d) Isoelectronic

Answer: (b) Isotopes

Both are Uranium (same Z = 92) but have different mass numbers (235 and 238) and therefore different numbers of neutrons (143 and 146). ^{235}U is fissile (used in reactors and bombs); ^{238}U is more abundant but not directly fissile. Same element, different mass = **Isotopes**.

🧠 TRICKY QUESTIONS **Isotopes, Isobars & Isotones — Conceptual Traps**

Q. $^{39}_{19}K$ and $^{40}_{20}Ca$ — What is the relationship between these two?

Answer: Isotones (same number of neutrons)

K: neutrons = 39 − 19 = **20**

Ca: neutrons = 40 − 20 = **20**

Same neutron count (N=20), but different Z and different A → they are **Isotones**.

Common trap: students see the A values are close (39, 40) and assume isobars (A must be exactly same for isobars — not close).

Q. Do isotopes of an element have the same chemical properties? Why?

Answer: Yes — because they have the same electronic configuration.

Chemical properties depend on the number and arrangement of electrons (especially valence electrons), NOT on neutrons. Isotopes have the same Z → same electron count → same electronic configuration → same chemical behaviour.

Physical properties (mass, density, melting point) differ because A differs. ^1H_2O, ^2H_2O (heavy water), ^3H_2O all undergo the same chemical reactions but have different densities and boiling points.

4. Electronic Configuration

4.1 Shell Filling — Rules and Configuration

Three rules govern how electrons fill orbitals — all three are NDA-tested

① Aufbau Principle

- Electrons fill orbitals in **increasing order of energy**
- Lower energy orbitals fill first before higher ones
- Energy order: 1s < 2s < 2p < 3s < 3p < 4s <

② Pauli Exclusion Principle

- No two electrons in an atom can have the **same set of all four quantum numbers**
- An orbital can hold **maximum 2**

③ Hund's Rule of Maximum Multiplicity

- Within the **same subshell**, electrons occupy orbitals singly first before pairing
- All singly occupied orbitals have the

- 3d < 4p ...
- Remember: **4s fills before 3d** (counter-intuitive!)
- Aufbau = "building up" in German

electrons, with opposite spins (↑↓)

- s subshell: 1 orbital → 2 electrons max
- p subshell: 3 orbitals → 6 electrons max
- d subshell: 5 orbitals → 10 electrons max

same spin direction (↑↑↑)

- Pairing only after all orbitals of that subshell are half-filled
- Maximises total spin → greater stability
- Explains paramagnetism of partially filled orbitals

ORBITAL FILLING ORDER — MEMORY AID

Orbital capacity: s=2, p=6, d=10, f=14

Filling order (Aufbau):

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6$ ...

Arrow diagonal trick (n + l rule):

Fill orbitals in increasing order of (n + l); if equal, lower n fills first.

3d: n+l = 3+2 = 5 | 4s: n+l = 4+0 = 4 → 4s fills before 3d ✓

4p: n+l = 4+1 = 5 | 3d: n+l = 3+2 = 5 → 3d fills before 4p (lower n) ✓

For NDA (shell notation): use K(2) L(8) M(18) N(32) with outer shell max 8. The orbital notation ($1s^2\ 2s^2\ 2p^6$ ...) is for higher-level questions.

Hydrogen
H (Z=1)
K: 1 | Config: $1s^1$
Valence e⁻: 1

Carbon
C (Z=6)
K:2, L:4 | $1s^2 2s^2 2p^2$
Valence e⁻: 4

Nitrogen
N (Z=7)
K:2, L:5 | $1s^2 2s^2 2p^3$
Valence e⁻: 5

Oxygen
O (Z=8)
K:2, L:6 | $1s^2 2s^2 2p^4$
Valence e⁻: 6

Sodium
Na (Z=11)
K:2, L:8, M:1 | $[Ne]3s^1$
Valence e⁻: 1

Chlorine
Cl (Z=17)
K:2, L:8, M:7 | $[Ne]3s^2 3p^5$
Valence e⁻: 7

Calcium
Ca (Z=20)
K:2, L:8, M:8, N:2
Valence e⁻: 2

Argon
Ar (Z=18)
K:2, L:8, M:8
Noble gas (0)

📋 **Valence Electrons and Valency:**

Valence electrons = electrons in the outermost shell. They determine chemical reactivity and bonding.

Valency = number of electrons an atom gains, loses, or shares to achieve the nearest noble gas configuration (stable octet or duplet for H, Li).

Rule: If valence electrons ≤ 4 → valency = valence electrons (tends to lose/share). If valence electrons ≥ 5 → valency = 8 − valence electrons (tends to gain).

Na (1 valence e^-) → valency = 1 (loses 1e^-). Cl (7 valence e^-) → valency = 8−7 = 1 (gains 1e^-).

📝 TOPIC-WISE PYQ

Electronic Configuration — NDA Pattern Questions

Q1. The electronic configuration of phosphorus (Z=15) is:

(a) 2, 8, 5 (b) 2, 8, 4, 1 (c) 2, 5, 8 (d) 2, 8, 3, 2

Answer: (a) 2, 8, 5

Z=15 electrons fill shells: K=2, L=8 (full), remaining = 15−10 = 5 → M=5.

Configuration: K:2, L:8, M:5 → written as 2,8,5. Valence electrons = 5; Valency = 8−5 = 3.

Q2. An element with electronic configuration 2,8,2 belongs to which period and group?

(a) Period 2, Group II (b) Period 3, Group II (c) Period 2, Group 12 (d) Period 4, Group 2

Answer: (b) Period 3, Group II

Total electrons = 2+8+2 = 12, so Z=12 = Magnesium (Mg). Number of shells = 3 → Period 3. Valence electrons = 2 → Group II (Group 2). Mg configuration: K:2, L:8, M:2.

Q3. According to Hund's rule, the three 2p electrons in nitrogen (Z=7) are arranged as:

(a) ↑↓ in one orbital, ↑ in second, empty third (b) ↑ in each of three separate orbitals (c) ↑↓ in each orbital (d) All in one orbital

Answer: (b) ↑ in each of three separate orbitals

Nitrogen has 3 electrons in the 2p subshell (which has 3 orbitals: 2p_x, 2p_y, 2p_z). By Hund's rule, electrons occupy each orbital singly with parallel spin before any pairing occurs: ↑ | ↑ | ↑. This gives maximum spin multiplicity and greater stability. Pairing would occur only with the 4th electron onwards (e.g., in O, Z=8: ↑↓ | ↑ | ↑).

🧠 TRICKY QUESTIONS **Electronic Configuration — Exceptions and Traps**

Q. Copper (Z=29) has configuration [Ar] $3d^{10}$ $4s^1$ instead of expected [Ar] $3d^9$ $4s^2$. Why?

Answer: Extra stability of completely filled d-subshell

The expected configuration by Aufbau would be [Ar] $3d^9$ $4s^2$. However, a **fully filled d subshell ($3d^{10}$) is extra stable** — it has symmetrical charge distribution and exchange energy. So one electron from 4s migrates to 3d, giving [Ar] $3d^{10}$ $4s^1$. Similarly, Chromium (Z=24): expected [Ar] $3d^4$ $4s^2$ but actual is [Ar] $3d^5$ $4s^1$ (half-filled d is also extra stable). These are classic NDA exceptions — **Cu and Cr**.

Q. Calcium (Z=20) has configuration 2,8,8,2 — but the M shell can hold 18 electrons. Why is it not 2,8,10?

Answer: The outermost shell follows the octet rule (max 8) during shell-by-shell filling

The $2n^2$ rule gives the maximum possible capacity, but electrons do not simply fill shells to maximum before starting the next. After M shell has 8 electrons (filling 3s and 3p), the next 2 electrons (for Ca) go into the N shell ($4s^2$) because 4s has lower energy than 3d. The 3d orbitals of M shell fill only after 4s is occupied. This is why Ca is 2,8,8,2 and not 2,8,10. The M shell's full 18 is achieved only by elements Z=28 onwards (when 3d is fully filled).

5. Quantum Numbers — Basic MCQ Concepts

5.1 **The Four Quantum Numbers**

Each electron is uniquely described by four quantum numbers — Pauli's basis

Quantum numbers are like an electron's "address" within an atom — they specify which shell, subshell, orbital, and spin orientation the electron occupies. NDA tests these at the identification and definition level, not calculation level.

Quantum Number	Symbol	What it describes	Allowed values	Determines
Principal	n	Shell / energy level (distance from nucleus)	1, 2, 3, 4 ... (positive integers)	Size & energy of orbital; n=1 is K shell
Azimuthal (Angular momentum)	l	Subshell / shape of orbital	0 to (n−1); for n=3: l=0,1,2	Shape of orbital (l=0:s, 1:p, 2:d, 3:f)
Magnetic	m or m_l	Orientation of orbital in space	-l to +l (including 0); total (2l+1) values	Number of orbitals in subshell
Spin	s or m_s	Spin of electron	+½ (↑) or -½ (↓) only	Direction of electron spin (clockwise/anticlockwise)

📋 Subshell Names & Orbital Count

- **s subshell** (l=0): 1 orbital → max 2 electrons
- **p subshell** (l=1): 3 orbitals → max 6 electrons
- **d subshell** (l=2): 5 orbitals → max 10 electrons
- **f subshell** (l=3): 7 orbitals → max 14 electrons
- Total orbitals in shell n = n^2 | Total e^- = $2n^2$

📌 Quick Values for n=2 (NDA example)

- n=2 → l can be 0 or 1 (two subshells: 2s, 2p)
- For l=0 (2s): m=0 only → 1 orbital
- For l=1 (2p): m=−1,0,+1 → 3 orbitals
- Total orbitals in n=2 shell = 1+3 = 4 = n^2
- Total electrons = 8 = $2n^2$

📌 NDA-level Quantum Number Questions — What to Expect:

(1) "What is the value of l for a p electron?" → l = 1

(2) "How many orbitals are in the 3d subshell?" → 2l+1 = 2(2)+1 = 5

(3) "Which quantum number determines the shape of an orbital?" → Azimuthal (l)

(4) "Maximum electrons in n=4 shell?" → $2n^2 = 2×16 = 32$

(5) "What are the possible values of m for l=2?" → −2, −1, 0, +1, +2 (five values)

TOPIC-WISE PYQ

Quantum Numbers — NDA Pattern Questions

Q1. The maximum number of electrons that can be accommodated in the shell with principal quantum number n = 3 is:

(a) 8 (b) 18 (c) 32 (d) 6

Answer: (b) 18

Maximum electrons = $2n^2 = 2 × (3)^2 = 2 × 9 =$ **18**. The M shell (n=3) contains subshells 3s ($2e^-$) + 3p ($6e^-$) + 3d ($10e^-$) = 18 electrons total.

Q2. Which quantum number determines the shape of an atomic orbital?

(a) Principal quantum number (n) (b) Azimuthal quantum number (l) (c) Magnetic quantum number (m) (d) Spin quantum number (s)

Answer: (b) Azimuthal quantum number (l)

l=0 → spherical (s orbital); l=1 → dumbbell-shaped (p orbital); l=2 → double dumbbell (d orbital). The principal quantum number n determines the size/energy. The magnetic quantum number m determines the orientation in space. Spin s determines the direction of electron spin only.

Q3. How many electrons can be present in the 3p subshell?

(a) 2 (b) 6 (c) 10 (d) 14

Answer: (b) 6

The p subshell (l=1) has 3 orbitals (m = −1, 0, +1). Each orbital holds 2 electrons (Pauli exclusion). So p subshell max = 3 × 2 = **6 electrons**. This applies to 2p, 3p, 4p, etc. — the number is always 6 regardless of the shell.

🧠 TRICKY QUESTIONS **Quantum Numbers — Common NDA Conceptual Traps**

Q. Can two electrons in the same atom have quantum numbers n=2, l=1, m=0, s=+½ for both? What principle is violated?

Answer: No — this violates the Pauli Exclusion Principle.
All four quantum numbers (n, l, m, s) are identical for both electrons — which is forbidden. The Pauli Exclusion Principle states no two electrons in the same atom can have the same set of all four quantum numbers. The only way two electrons can share n=2, l=1, m=0 is if one has s=+½ and the other has s=−½ (opposite spins: ↑↓).

Q. An electron has n=3, l=2. In which subshell is it? How many electrons can this subshell hold?

Answer: 3d subshell — holds maximum 10 electrons.
n=3 → third shell (M); l=2 → d subshell. So it's the **3d subshell**.
Number of orbitals = 2l+1 = 2(2)+1 = 5 orbitals.
Each orbital holds 2 electrons → 5 × 2 = **10 electrons** maximum in 3d.
Remember: 3d fills after 4s (Aufbau) even though it's inside the M shell.

📄 CNo2 Formula & Fact Sheet — Quick Reference

⚛ Atomic Number & Mass

- Z = protons = electrons (neutral atom)
- A = protons + neutrons = Z + N
- Neutrons N = A − Z
- Notation: $^{A}_{Z}X$ → $^{23}_{11}Na$: Z=11, A=23, N=12
- Max electrons per shell: $2n^2$

🔬 Isotopes / Isobars / Isotones

- Isotopes: same Z, different A (same element, different mass)
- Isobars: same A, different Z (^{14}C and ^{14}N)
- Isotones: same N = A−Z (^{39}K and ^{40}Ca, both N=20)
- Isoelectronic: same electron count (Na^+, Mg^{2+}, Ne all = $10e^-$)

- Isotopes: same chemistry, different physical properties

🔮 Quantum Numbers

- n (principal): shell, energy — values 1,2,3,4
- l (azimuthal): shape — 0 to (n−1); s=0, p=1, d=2, f=3
- m (magnetic): orientation — −l to +l; (2l+1) values
- s (spin): +½ or −½ only
- Orbitals in subshell = 2l+1 | Electrons = 2(2l+1)

⚡ Three Filling Rules

- Aufbau: fill lowest energy first (4s before 3d)
- Pauli: max $2e^-$ per orbital, opposite spins
- Hund's: fill each orbital singly in subshell before pairing
- Exceptions: Cu = $[Ar]3d^{10}4s^1$; Cr = $[Ar]3d^5 4s^1$
- Valency: if v.e ≤4 → valency = v.e; if v.e ≥5 → valency = 8−v.e

📌 Bohr's Model Formulae

- $E_n = -13.6/n^2$ eV (H atom energy levels)
- $r_n = 0.529 \times n^2$ Å (orbit radius)
- $\Delta E = h\nu = 13.6(1/n_1^2 - 1/n_2^2)$ eV
- Balmer series: visible light, $n_1=2$
- Lyman series: UV, $n_1=1$

📈 Subatomic Particles

- Proton: +1 charge, mass ≈1 amu, inside nucleus
- Neutron: 0 charge, mass ≈1 amu, inside nucleus
- Electron: −1 charge, mass = 1/1836 amu, outer shells
- Discovered: e^- by Thomson; p^+ by Rutherford; n^0 by Chadwick
- Nucleus diameter ≈10^{-15} m; atom ≈10^{-10} m

⚡ Quick Revision Booster — CN02 Atomic Structure

🔋 Atomic Models Sequence

- Dalton (1808): solid indivisible sphere

🔮 Particle Shortcut

- Z = protons = electrons (neutral atom)

🔬 Iso-Triples (learn the examples)

- Isotopes: ^1H, ^2H, ^3H | ^{12}C, ^{14}C | ^{235}U, ^{238}U

- Thomson (1897): plum pudding, e^- discovered
- Rutherford (1911): nuclear model, gold foil
- Bohr (1913): fixed orbits, explains H spectrum
- Rutherford's flaw: orbiting e^- should spiral → collapse

- N (neutrons) = A − Z (always compute this first)
- Mass ≈ protons + neutrons (electrons negligible)
- Chadwick (1932) discovered neutron — last subatomic particle
- Electron mass = 1/1836 proton mass ≈ 0 for mass number

- Isobars: ^{14}C and ^{14}N | ^{40}Ar and ^{40}Ca
- Isotones: ^{39}K and ^{40}Ca (N=20 for both)
- Isoelectronic: Na^+, Mg^{2+}, Al^{3+}, Ne, F^-, O^{2-} (all $10e^-$)
- Key: Isotopes → same Z; Isobars → same A; Isotones → same N

📋 Shell Filling Shortcuts

- K=2, L=8, M=18, N=32 ($2n^2$ rule)
- Outer shell max = 8 always (octet)
- 4s fills before 3d (Aufbau — n+l rule)
- Cu $[Ar]3d^{10}4s^1$; Cr $[Ar]3d^54s^1$ (exceptions)
- Valence e^- = electrons in last shell

⚛ Quantum Number Facts

- n → shell/size (1=K, 2=L, 3=M, 4=N)
- l → shape (0=s, 1=p, 2=d, 3=f)
- m → orientation (2l+1 values)
- s → spin (+½ or −½)
- Pauli: no two e^- same all four QN

🚨 Common Traps

- Isotopes have same chemical properties (same electrons)
- Isobars: same A but different elements (different Z)
- 39K and 40Ca are isotones, NOT isobars (A is different)
- 3d fills after 4s — M shell's 18 fills late
- 1 mole of any atom contains N_a = 6.022×10^{23} atoms

📝 Mock Tests | 🎯 Subject Quizzes | ✈️ Telegram