4.3.10 Formation of Coloured Ions

Unlocking the optical signatures of d-block transition elements.



s & p Block Elements



Typically form colourless or white compounds.

d-Block Elements



Famous for forming a vast array of brilliantly coloured complexes and aquated ions.

This unique optical property arises entirely from the behaviour of electrons residing in the penultimate d-orbitals.

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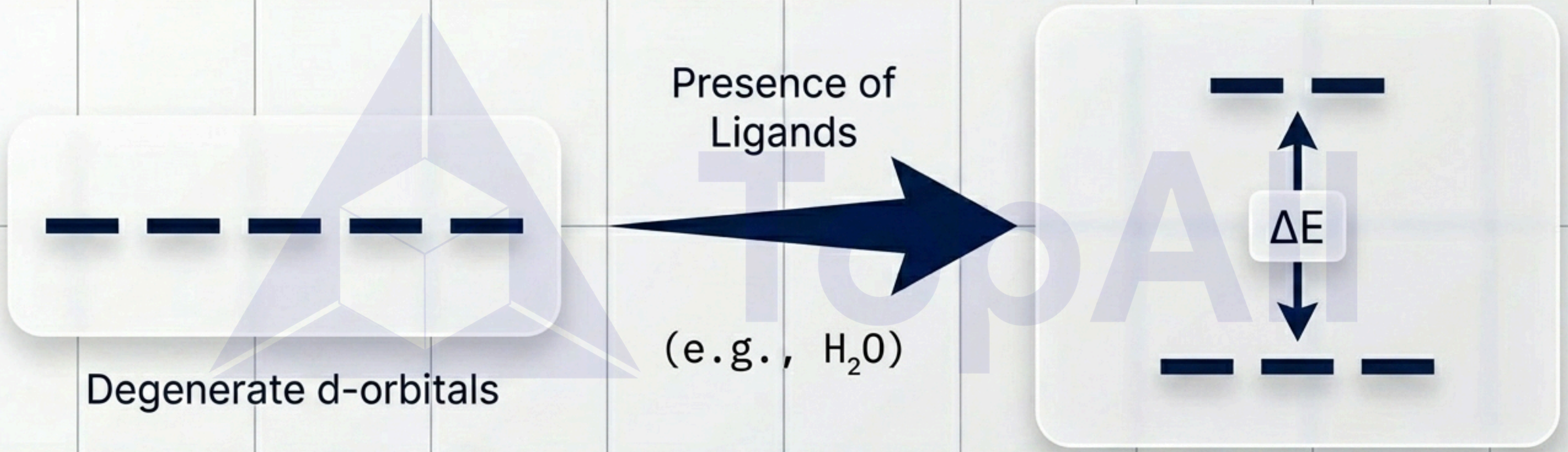
The Microscopic Prerequisite

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Not all transition metal ions are coloured. To exhibit colour, an ion must possess an incompletely filled d-subshell.

Crystal Field Splitting

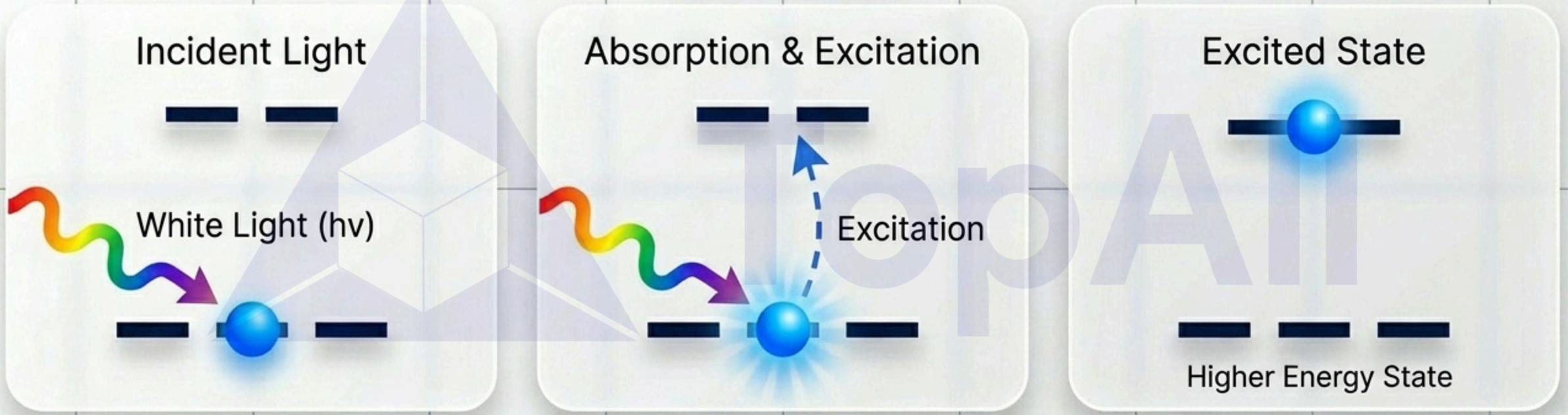


Ligands break the symmetry. The 5 degenerate d-orbitals split into two distinct energy levels, creating a specific energy gap.

Electron Excitation

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$$\Delta E = h\nu$$



The d-d Transition: When an electron from a lower energy d-orbital is excited to a higher energy d-orbital, the energy of excitation corresponds exactly to a frequency (ν) of visible light.





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Key Highlights

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- Climb the Leaderboard Among Fellow Aspirants
- Practice Unlimited MCQs for NEET & JEE
- Get Clear Explanations, Not Just Marks
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Complementary Colours



We do not see the light that fuels the d-d transition.

The colour observed by the human eye corresponds to the complementary colour of the light absorbed.

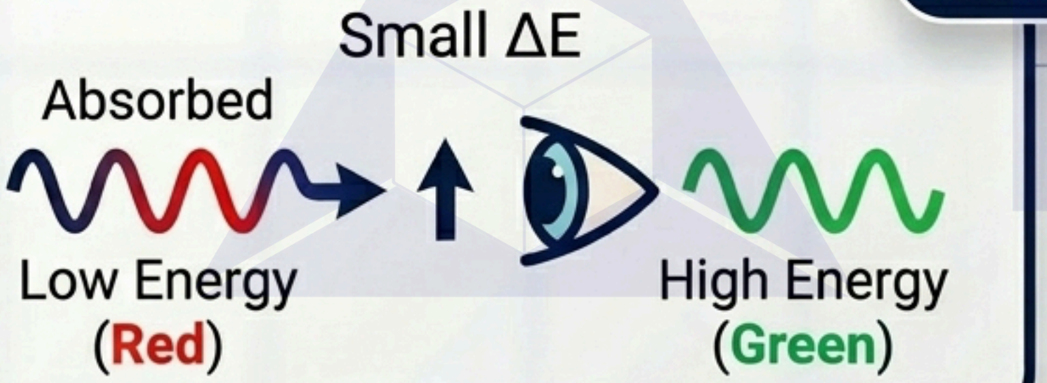
Example Chip

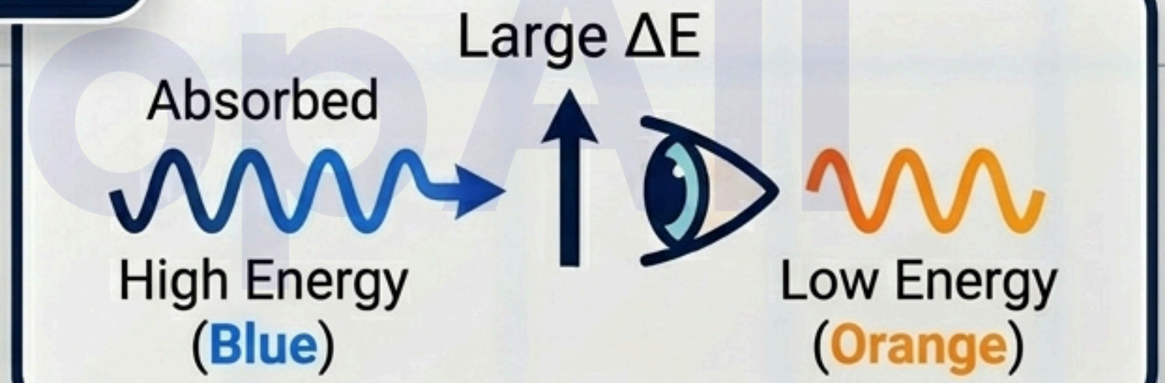
If an ion absorbs **RED** light → The transmitted light appears **GREEN**.

Quote Box

> The frequency of the light absorbed is determined by the nature of the ligand.

UI Slider





Changing the ligand changes the energy gap, which shifts the exact colour we observe.

d^0 Configuration



Sc^{3+} Ti^{4+}

Colourless. No electrons available to be excited.

d^{10} Configuration



Zn^{2+} Cu^{+}

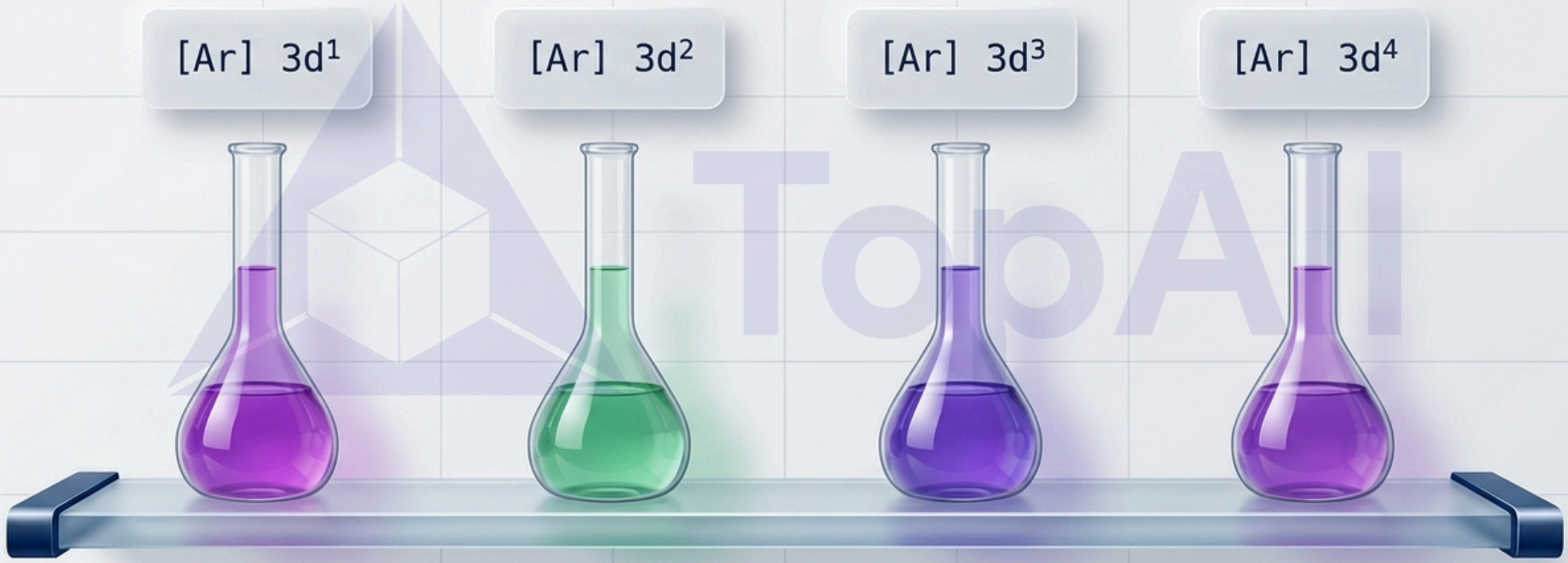
Colourless. No empty space in higher orbitals for an electron to jump into.

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Mapping the 3d Series (d^1 to d^4)

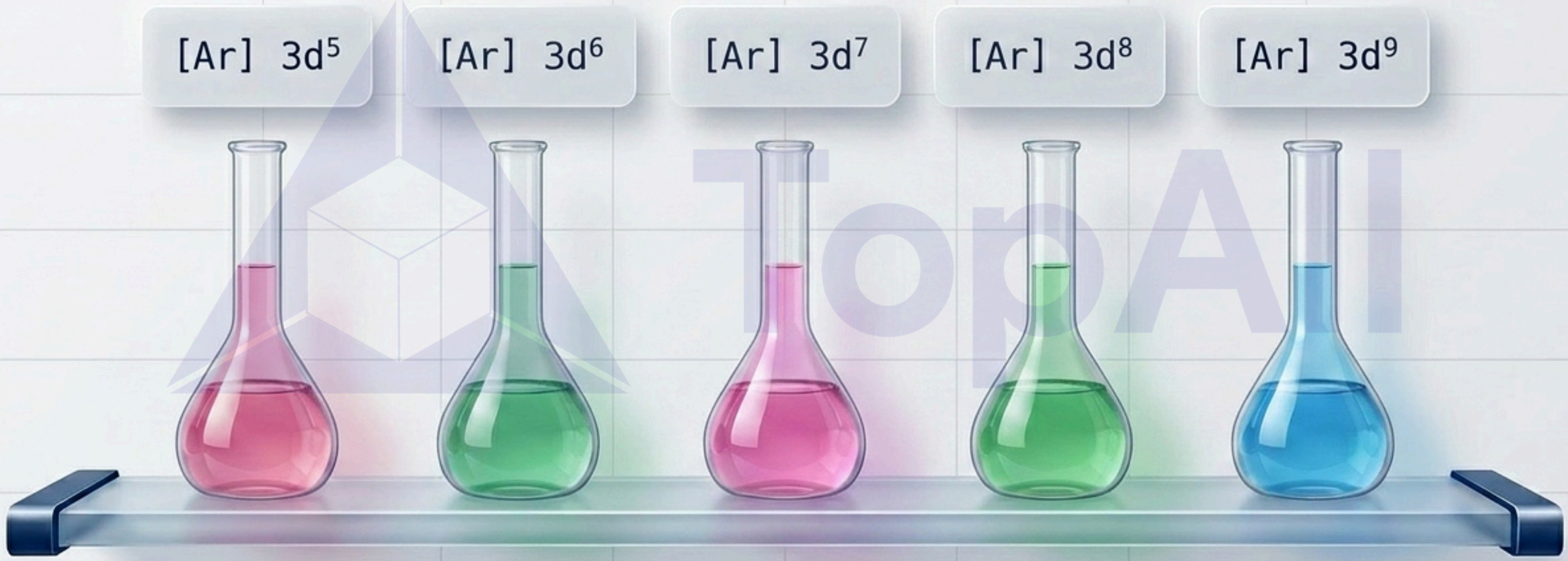
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All configurations shown are for aquated ions.



Mapping the 3d Series (d^5 to d^9)

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Isoelectronic Colour Groupings

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d^3 System

- V^{2+} → Violet
- Cr^{3+} → Violet

d^5 System

- Mn^{2+} → Pink
- Fe^{3+} → Yellow (Exception to the pattern)

d^6 System

- Fe^{2+} → Green
- Co^{3+} → Blue

Ions with identical d-electron counts often exhibit identical or closely related colours, though the changing nuclear charge can shift the exact wavelength.

Mechanism of Colour in Transition Metal Complexes

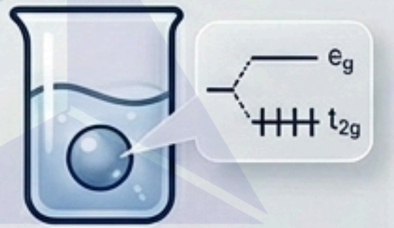
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Node 1



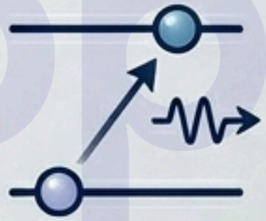
Incident White Light

Node 2



Incomplete d-orbitals split by ligands

Node 3



Specific ν absorbed for d-d transition

Node 4



Complementary colour observed

NEET/JEE Exam Tip: The ‘Colourless’ Trap

- **The Trap:** Exam questions often ask “Which of the following is coloured?” Don’t guess—always write the electronic configuration first!
- **Rapid Recall Heuristic:** Actively scan the options for Sc^{3+}, Ti^{4+}, Zn^{2+}, or Cu^{+}. If you see them, they are instantly d^0 or d^{10} → Colourless.
- **The Conceptual Link:** Paramagnetism and Colour usually go hand-in-hand. Both require the presence of unpaired d-electrons.

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Formation of Coloured Ions

Exceptions

d^0 and d^{10} are strictly colourless

Cause

Incomplete d-orbitals (d^1-d^9)

Observation

We see the Complementary Colour

Mechanism

d-d transitions split by ligands ($\Delta E = h\nu$)

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