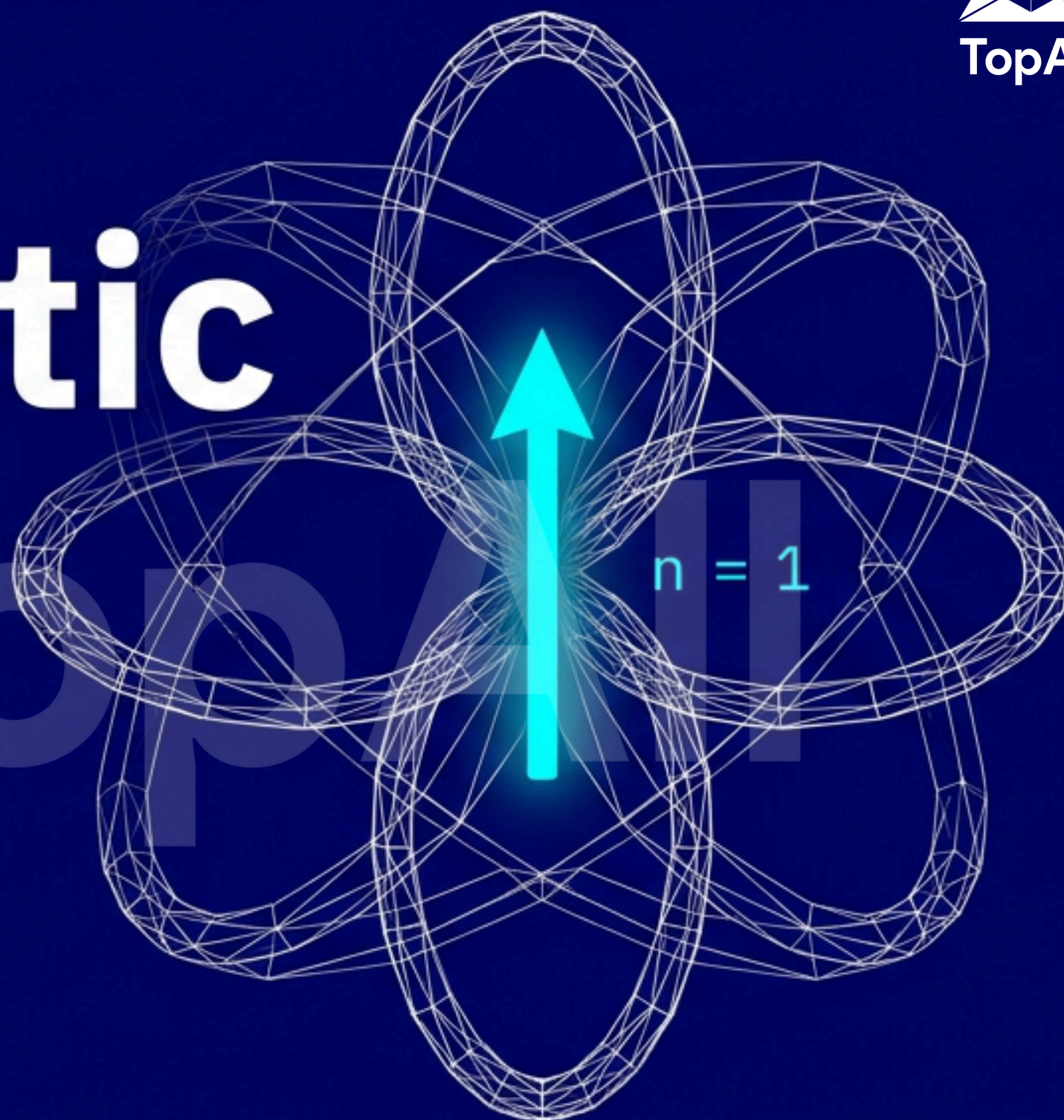


4.3.9 Magnetic Properties

From observable phenomena to the spin-only formula.



Classifying Magnetic Behaviour

How transition metals and their compounds react to an applied magnetic field.

Diamagnetism



Reaction: Repelled by the field.

Cause: All electrons are paired.



Paramagnetism



Reaction: Attracted to the field.

Cause: Presence of **unpaired electrons**.



Ferromagnetism

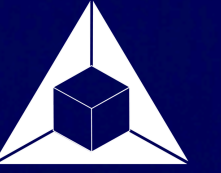


Reaction: Attracted very strongly.

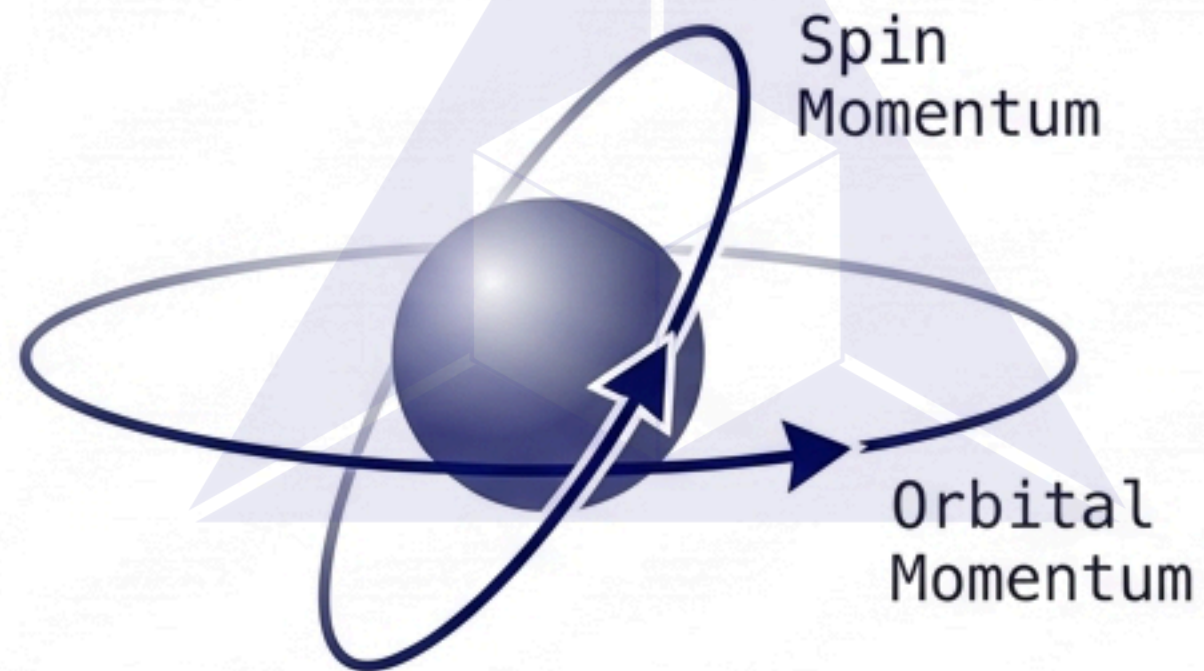
Note: An extreme form of paramagnetism.



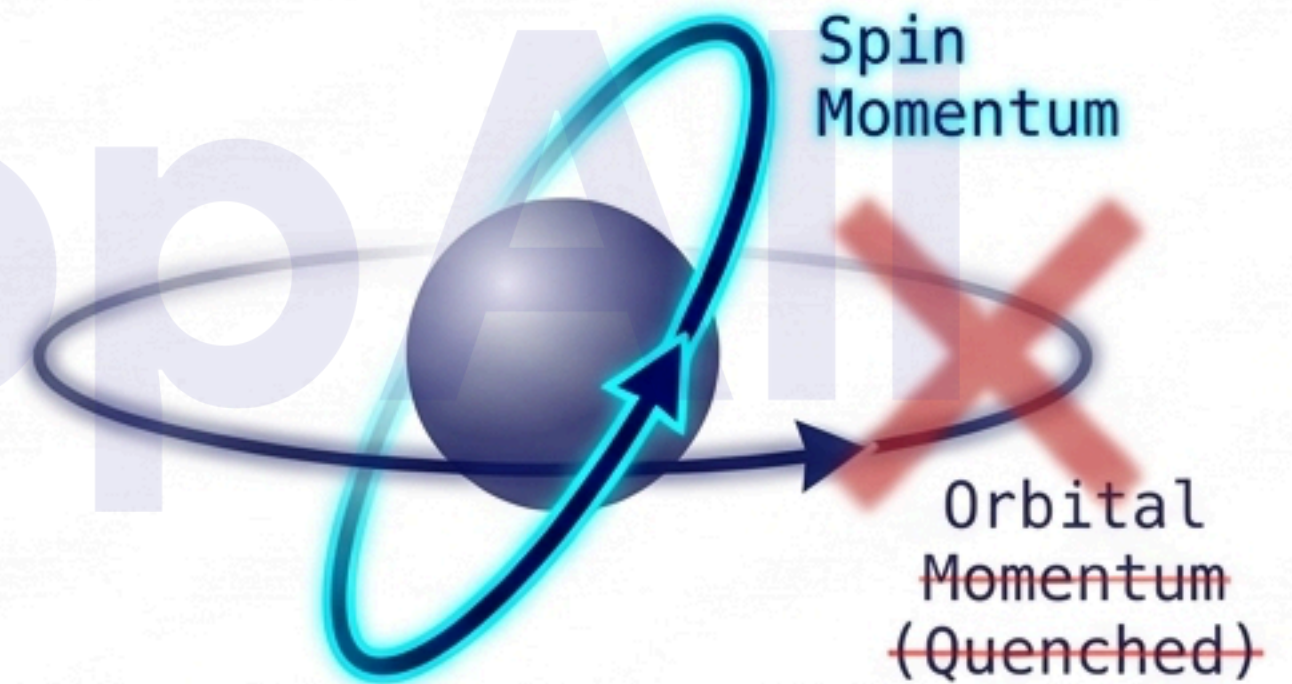
The Origin of Paramagnetism



Each unpaired electron acts as a micro-magnet. Its total magnetic moment comes from two sources: Spin Angular Momentum and Orbital Angular Momentum.



The 3d Metal Reality



In 3d transition metals, orbital angular momentum is effectively quenched (suppressed by the environment). We only calculate spin.



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$$E=mc^2$$



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The Spin-Only Formula

Calculating the magnetic moment of 3d transition metal ions.

$$\mu = \sqrt{n(n+2)}$$

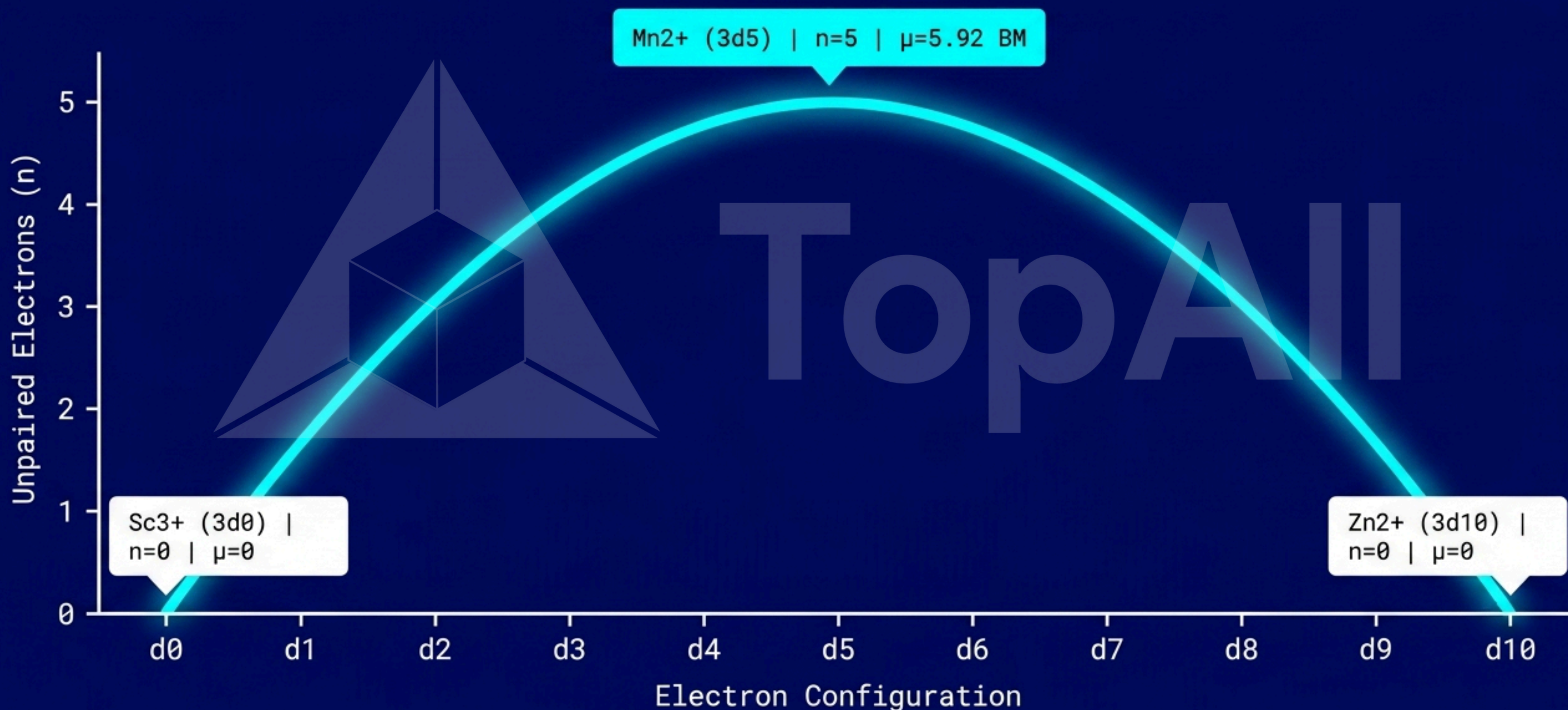
→ Magnetic Moment
(Units: Bohr Magneton, BM)

→ Number of unpaired
electrons

A single unpaired electron ($n=1$) has a magnetic moment of 1.73 BM.

The Magnetic Arch of the 3d Series

Magnetic moment increases with the number of unpaired electrons, peaking at d5.



Calculated vs. Observed Reality



Experimental data for hydrated ions in solution closely matches the spin-only calculation.

Ion	Configuration	Unpaired Electrons (n)	Calculated μ (BM)	Observed μ (BM)
Ti ³⁺	3d ¹	1	1.73	1.75
V ²⁺	3d ³	3	3.87	3.86
Mn ²⁺	3d ⁵	5	5.92	5.96
Ni ²⁺	3d ⁸	2	2.84	2.9 – 3.4

Notice the slight divergence due to unquenched orbital contributions.

Application: Calculating Magnetic Moment



Problem: Calculate the magnetic moment of a divalent ion in aqueous solution if its atomic number is 25.

Step 1: Identify the element.

$Z = 25$ is Manganese (Mn).

Step 2: Find the ion's configuration.

Divalent ion = Mn^{2+} . Neutral Mn is $3d^5 4s^2$. Therefore, Mn^{2+} is $3d^5$.

Step 3: Count unpaired electrons.

$3d^5$ has 5 unpaired electrons. ($n = 5$).

Step 4: Apply Formula.

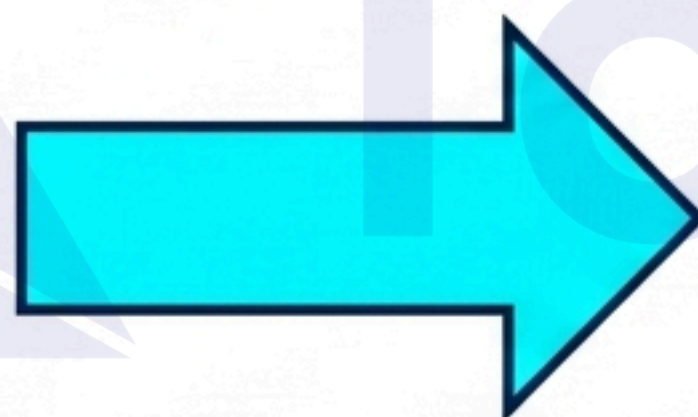
$$\mu = \sqrt{5(5+2)} = \sqrt{35} = 5.92 \text{ BM.}$$

NEET / JEE Exam Tip

The Integer Shortcut for Rapid MCQ Solving

The calculated magnetic moment (μ) always starts with the integer matching the number of unpaired electrons (n).

$$\begin{array}{l} n = 1 \\ n = 2 \\ n = 3 \\ n = 4 \\ n = 5 \end{array}$$



$$\begin{array}{l} \mu = 1.73 \\ \mu = 2.84 \\ \mu = 3.87 \\ 4 = 4.90 \\ \mu = 5.92 \end{array}$$

Takeaway: If a question gives you a magnetic moment of 4.90 BM, you instantly know the ion has 4 unpaired electrons without doing reverse math.

Quick Revision: Magnetic Properties

1. The Trigger

Unpaired Electrons



Unpaired electrons act as micro-magnets due to **their spin angular momentum**.

2. The Mechanism

Orbital Quenching



In 3d series elements, the orbital momentum is effectively **suppressed** by the surrounding environment.

3. The Calculation

Spin-Only Formula

$$\mu = \sqrt{n(n+2)}$$

Calculate the exact Bohr Magneton (BM) value **purely** based on the count of 'n'.



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