RG
Ram Govind Yadav
CHEMISTRY EDUCATOR

INORGANIC

CH 03

d- and f-Block Elements — Trends, $KMnO_4$, $K_2Cr_2O_7$ & Lanthanoids

Configurations and their exceptions, oxidation states, E° trends, colour, magnetism and catalysis, permanganate and dichromate chemistry, and the lanthanoid contraction — with an exam trap gallery, graded MCQs and a one-page revision sheet.

WHAT YOU WILL BE ABLE TO DO

- Write configurations for 3d atoms and ions, including Cr and Cu, and decide which elements count as transition elements
- Explain trends in radius, melting point, ionisation enthalpy and E° across the 3d series
- Calculate spin-only magnetic moments and predict whether an ion is coloured
- Write the preparation and key redox half-equations of $KMnO_4$ and $K_2Cr_2O_7$ in each medium
- Explain the lanthanoid contraction and compare lanthanoids with actinoids

INSIDE

A The big picture
B Electronic configuration
C Trends across the 3d series
D Oxidation states and E°
E Colour, magnetism and catalysis
F Potassium permanganate

HOW TO USE THESE NOTES

IN ONE LINE The core idea of a section	**KEY IDEA** The concept to remember	**EXAM TRAP** Where marks are usually lost
SOLVED EXAMPLE Worked step by step	**CHECK YOURSELF** Quick self-test	**MEMORY HOOK** A line that sticks

SECTION A

The big picture

A

Every property in this chapter traces back to the d electrons.

IN ONE LINE

A transition element has an incompletely filled d subshell in the atom or in a common ion. Partly filled d orbitals give variable oxidation states, coloured and paramagnetic ions, complexes and catalytic power.

- **d-block:** groups 3–12, four series (3d, 4d, 5d, 6d). General configuration $(n-1)d^{1-10}\ ns^{1-2}$.
- **f-block:** lanthanoids (4f, Ce–Lu) and actinoids (5f, Th–Lr), placed separately at the foot of the table.
- **Zn, Cd and Hg** have a full d^{10} subshell in the atom and in their common +2 ion, so they are d-block elements but not transition elements.

THINK OF IT LIKE THIS

Think of the d subshell as a five-room hostel. Half-full (one in every room) or full is a stable, settled state. Most of the "odd" behaviour you will meet — the Cr and Cu configurations, Mn^{2+} being stable, Cu^{+} being colourless — is the hostel trying to reach one of those two states.

SECTION B

Electronic configuration

B

Fill 4s first, remove 4s first.

Element	Z	Configuration	Common ions
Sc	21	[Ar] $3d^1\ 4s^2$	Sc^{3+} (d^0)
Ti	22	[Ar] $3d^2\ 4s^2$	Ti^{3+}, Ti^{4+}
V	23	[Ar] $3d^3\ 4s^2$	V^{3+}, V^{5+}
Cr	24	**[Ar] $3d^5\ 4s^1$**	Cr^{3+} (d^3), Cr^{6+}
Mn	25	[Ar] $3d^5\ 4s^2$	Mn^{2+} (d^5), Mn^{7+}
Fe	26	[Ar] $3d^6\ 4s^2$	Fe^{2+} (d^6), Fe^{3+} (d^5)

Element	Z	Configuration	Common ions
Co	27	[Ar] $3d^7\ 4s^2$	Co^{2+}, Co^{3+}
Ni	28	[Ar] $3d^8\ 4s^2$	Ni^{2+} (d^8)
Cu	29	**[Ar] $3d^{10}\ 4s^1$**	Cu^{+} (d^{10}), Cu^{2+} (d^9)
Zn	30	[Ar] $3d^{10}\ 4s^2$	Zn^{2+} (d^{10})

KEY IDEA

When a 3d atom forms an ion, the 4s electrons leave first. Fe is $3d^6\ 4s^2$, so Fe^{2+} is $3d^6$ and Fe^{3+} is $3d^5$ — not $3d^4\ 4s^2$.

SOLVED EXAMPLE 01 — IS COPPER A TRANSITION ELEMENT?

Cu has a full $3d^{10}$ subshell. Why is it still called a transition element, while Zn is not?

SOLUTION

1. The definition allows an incompletely filled d subshell in the atom **or in a common ion**.
2. Cu^{2+} is $3d^9$ — incomplete. Cu^{2+} is Cu's most common ion.
3. Zn's only common ion, Zn^{2+}, is $3d^{10}$ — complete.

ANSWER Cu qualifies through Cu^{2+} ($3d^9$); Zn never has an incomplete d subshell.

SECTION C

Trends across the 3d series

Small, steady changes — with a few famous exceptions.

- **Atomic radius** falls from Sc to Cr, stays almost constant through the middle (extra d electrons shield the extra nuclear charge), then rises slightly at Cu and Zn.
- **4d and 5d radii are almost equal** (Zr 160 pm, Hf 159 pm) because of the lanthanoid contraction — see Section H.
- **Melting points** are high (strong metallic bonding from many unpaired d electrons), peak around the middle (V, Cr), dip at **Mn** (stable d^5, fewer electrons in bonding) and fall to a low at **Zn**. W has the highest melting point of all metals; Hg is a liquid.
- **Ionisation enthalpy** rises only slowly across the series. Irregular jumps come from the stability of d^5 and d^{10}: $Mn^{2+} \rightarrow Mn^{3+}$ and $Zn^{2+} \rightarrow Zn^{3+}$ are especially hard.
- **Density** increases across the series; d-block metals are much denser than s-block metals.

CHECK YOURSELF

C1 Why is the melting point of Mn lower than that of Cr and Fe?

C2 Why are Zr and Hf so difficult to separate?

Answers at the end of the chapter.

SECTION D

D

Oxidation states and E°

How many electrons can a metal give away, and how willingly?

Because 4s and 3d have similar energies, transition metals use both, giving **variable oxidation states** differing by one. The number of states peaks at Mn (+2 to +7). The highest oxidation state of the d-block is +8 (Os in OsO_4).

- High oxidation states are stabilised by **O and F**: MnO_4^- (+7), CrO_4^{2-} (+6), VF_5 (+5). Oxygen also forms multiple bonds, so oxides reach higher states than fluorides (Mn_2O_7 exists, MnF_7 does not).
- Low oxidation states (0, +1) appear with π-acceptor ligands such as CO: $Ni(CO)_4$, $Fe(CO)_5$.
- Oxides become **more acidic** as the oxidation state rises: MnO (basic) → Mn_2O_3, MnO_2 (amphoteric) → Mn_2O_7 (acidic).

Couple	E° / V	What it tells you
Mn^{2+}/Mn	−1.18	Mn is a fairly strong reducing agent
Zn^{2+}/Zn	−0.76	Stable d^{10} Zn^{2+}
Fe^{2+}/Fe	−0.44	
Cu^{2+}/Cu	**+0.34**	The only positive E° in the 3d series: Cu does not release H_2 from dilute acids
Mn^{3+}/Mn^{2+}	+1.57	Mn^{3+} is a strong oxidant: Mn^{2+} is d^5 (half-filled)
Co^{3+}/Co^{2+}	+1.97	Co^{3+} is an even stronger oxidant in water
Cr^{3+}/Cr^{2+}	−0.41	Cr^{2+} is a reducing agent: Cr^{3+} is d^3 (stable half-filled t_2g)
Fe^{3+}/Fe^{2+}	+0.77	Fe^{3+} (d^5) is the more stable ion

SOLVED EXAMPLE 02 — Mn^{3+} VERSUS Cr^{3+}

Explain why Cr^{2+} is reducing while Mn^{3+} is oxidising, though both are d^4.

SOLUTION

1. Cr^{2+} (d^4) → Cr^{3+} (d^3): losing one electron gives a half-filled t_{2g} set, which is especially stable. So Cr^{2+} gives electrons away readily.
2. Mn^{3+} (d^4) → Mn^{2+} (d^5): gaining one electron gives a half-filled d^5 set. So Mn^{3+} takes electrons readily.

ANSWER Both ions move toward a half-filled configuration — one by losing, the other by gaining an electron.

KEY IDEA

Cu^+ disproportionates in water: $2Cu^+ \rightarrow Cu^{2+} + Cu$. Cu^{2+} is smaller and more highly charged, so its hydration enthalpy is much larger and more than pays for the second ionisation enthalpy.

SECTION E

Colour, magnetism and catalysis

E

Three properties, one cause: unpaired or partly filled d orbitals.

Magnetism

$$\mu \text{ (spin-only)} = \sqrt{[n(n+2)]} \text{ BM}$$

n = number of unpaired electrons; BM = Bohr magneton

Unpaired electrons (n)	1	2	3	4	5
μ / BM	1.73	2.83	3.87	4.90	5.92
Example ion	Ti^{3+}, Cu^{2+}	V^{3+}, Ni^{2+}	Cr^{3+}	Fe^{2+}	Mn^{2+}, Fe^{3+}

Colour

In a complex or a hydrated ion, the d orbitals split into two energy sets. An electron absorbs visible light to jump between them (a **d–d transition**), and we see the complementary colour. **No d electrons (d^0) or a full set (d^{10}) means no d–d transition — colourless:** Sc^{3+}, Ti^{4+}, Zn^{2+}, Cu^+.

Ion	Configuration	Colour in water
Ti^{3+}	$3d^1$	Purple
V^{3+}	$3d^2$	Green
Cr^{3+}	$3d^3$	Violet

Ion	Configuration	Colour in water
Mn^{2+}	$3d^5$	Pale pink
Fe^{2+}	$3d^6$	Pale green
Fe^{3+}	$3d^5$	Yellow
Co^{2+}	$3d^7$	Pink
Ni^{2+}	$3d^8$	Green
Cu^{2+}	$3d^9$	Blue
Zn^{2+}	$3d^{10}$	Colourless

Catalysis, interstitial compounds and alloys

- **Catalysts** because they show variable oxidation states and offer surfaces for adsorption: Fe in the Haber process, V_2O_5 in the contact process, Ni in hydrogenation, Pt/Rh in catalytic converters.
- **Interstitial compounds:** small atoms (H, C, N) fit into gaps in the metal lattice (TiC, Fe_3H, Mn_4N). They are hard, high-melting, conduct electricity and are chemically inert.
- **Alloys** form easily because the atomic radii are similar (within about 15%): brass (Cu + Zn), bronze (Cu + Sn), stainless steel (Fe + Cr + Ni).

SOLVED EXAMPLE 03 — SPIN-ONLY MOMENT

Calculate the spin-only magnetic moment of Fe^{2+} (Z = 26).

SOLUTION

1. Fe is [Ar] $3d^6\ 4s^2$; Fe^{2+} loses the two 4s electrons: $3d^6$.
2. In five d orbitals, six electrons give four unpaired (one pair + four singles).
3. $\mu = \sqrt{[4 \times 6]} = \sqrt{24}$.

ANSWER $\mu \approx 4.90$ BM.

CHECK YOURSELF

C3 Which of these is colourless: Ti^{3+}, Cu^{+}, V^{3+}?

C4 An ion has μ = 3.87 BM. How many unpaired electrons does it have?

Answers at the end of the chapter.

SECTION F

Potassium permanganate, $KMnO_4$

F

Purple, powerful, and the answer depends on the medium.

Preparation

1. **Fuse MnO_2 with KOH in air (or with KNO_3):** $2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4$ (green manganate) $+ 2H_2O$.
2. **Oxidise manganate to permanganate** — by disproportionation in neutral or acidic solution, $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$, or commercially by electrolytic oxidation in alkaline solution.

Structure: in MnO_4^- the Mn is +7 (d^0) and tetrahedral. Its intense purple colour is **not** a d–d transition — it comes from charge transfer (an electron moving from O to Mn).

The three media

Medium	Half-equation	Mn changes	Electrons
Acidic (dil. H_2SO_4)	$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	+7 → +2 (colourless)	5
Neutral / weakly alkaline	$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$	+7 → +4 (brown ppt)	3
Strongly alkaline	$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	+7 → +6 (green)	1

- **Acidic** oxidations: $Fe^{2+} \rightarrow Fe^{3+}$; $C_2O_4^{2-} \rightarrow CO_2$; $I^- \rightarrow I_2$; $H_2S \rightarrow S$; $SO_2 \rightarrow SO_4^{2-}$; $NO_2^- \rightarrow NO_3^-$.
- **Neutral/alkaline** oxidations: $I^- \rightarrow IO_3^-$ (iodate, not iodine); $S_2O_3^{2-} \rightarrow SO_4^{2-}$; $Mn^{2+} \rightarrow MnO_2$.
- $KMnO_4$ is its own indicator: the first permanent pink colour marks the end point.

KEY IDEA

Never acidify $KMnO_4$ with HCl: MnO_4^- oxidises Cl^- to Cl_2, so some permanganate is wasted and titres come out wrong. Use dilute H_2SO_4. HNO_3 is also avoided — it is an oxidant itself.

SOLVED EXAMPLE 04 — PERMANGANATE AND OXALATE

Write the balanced ionic equation for $KMnO_4$ oxidising oxalate in acid, and find the mole ratio.

SOLUTION

1. Reduction: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ (× 2).
2. Oxidation: $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ (× 5).
3. Add: $2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$.

ANSWER $MnO_4^- : C_2O_4^{2-} = 2 : 5$. (For Fe^{2+} the ratio is 1 : 5.)

SECTION G

Potassium dichromate, $K_2Cr_2O_7$

Orange, stable, and pH decides its form.

Preparation from chromite ore ($FeCr_2O_4$)

1. **Fuse with Na_2CO_3 in air:** $4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$.
2. **Acidify the yellow chromate:** $2Na_2CrO_4 + 2H^+ \rightarrow Na_2Cr_2O_7 + 2Na^+ + H_2O$.
3. **Add KCl:** $Na_2Cr_2O_7 + 2KCl \rightarrow K_2Cr_2O_7 + 2NaCl$. The potassium salt is less soluble and crystallises out.

$$2CrO_4^{2-}\ (\text{yellow}) + 2H^+ \rightleftharpoons Cr_2O_7^{2-}\ (\text{orange}) + H_2O$$

Add acid → orange; add alkali → yellow. Cr is +6 in both: this is not a redox change.

Structure: chromate is tetrahedral; dichromate is two tetrahedra sharing one oxygen (Cr–O–Cr bridge).

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+}\ (\text{green}) + 7H_2O$$

$E^\circ = +1.33$ V; Cr goes +6 → +3

- Oxidises $Fe^{2+} \rightarrow Fe^{3+}$ (ratio $Cr_2O_7^{2-} : Fe^{2+} = 1 : 6$), $I^- \rightarrow I_2$, $H_2S \rightarrow S$, $Sn^{2+} \rightarrow Sn^{4+}$, $SO_2 \rightarrow SO_4^{2-}$.
- Used as a **primary standard** in volumetric analysis (pure, stable, not hygroscopic) — unlike $KMnO_4$.
- **Chromyl chloride test** for Cl^-: chloride + $K_2Cr_2O_7$ + conc. H_2SO_4 gives red-orange CrO_2Cl_2 vapour.
- The old breath-analyser test: orange dichromate turns green as ethanol reduces it to Cr^{3+}.

SOLVED EXAMPLE 05 — DICHROMATE TITRATION

How many moles of Fe^{2+} are oxidised by 0.02 mol of $K_2Cr_2O_7$ in acid?

SOLUTION

1. Each $Cr_2O_7^{2-}$ accepts 6 electrons (two Cr, each +6 → +3).
2. Each Fe^{2+} gives 1 electron.
3. Moles $Fe^{2+} = 6 \times 0.02$.

ANSWER 0.12 mol of Fe^{2+}.

SECTION H

Lanthanoids

H

Fourteen elements that look almost alike.

- **Configuration:** [Xe] $4f^{1-14}\ 5d^{0-1}\ 6s^2$. The 4f electrons are buried deep, so they take little part in bonding.

- **Common oxidation state +3** for all. Ce also shows +4 ($4f^0$, a strong oxidant); Eu and Yb show +2 ($4f^7$ and $4f^{14}$, reducing).
- Many Ln^{3+} ions are coloured (f–f transitions); La^{3+} (f^0) and Lu^{3+} (f^{14}) are colourless.
- **Basicity of hydroxides decreases** from $La(OH)_3$ to $Lu(OH)_3$ as the ions shrink and covalent character rises.
- **Misch metal** (about 95% lanthanoids, 5% Fe) is used in lighter flints and Mg alloys.

KEY IDEA

Lanthanoid contraction: across the series the 4f electrons shield the growing nuclear charge poorly, so atomic and ionic radii fall steadily from La^{3+} to Lu^{3+}. Consequences: 4d and 5d elements of a group have almost the same size (Zr ≈ Hf, Nb ≈ Ta), lanthanoids are hard to separate, and basicity falls along the series.

SOLVED EXAMPLE 06 — WHY Ce^{4+} OXIDISES

Ce^{4+} is a good oxidising agent in water. Explain using configurations.

SOLUTION

1. Ce is [Xe] $4f^1\ 5d^1\ 6s^2$; Ce^{4+} is [Xe] $4f^0$ — a noble-gas core, so it can form.
2. But the usual, most stable state of a lanthanoid in water is +3.
3. Ce^{4+} therefore accepts an electron to return to Ce^{3+} ($E° \approx +1.74$ V).

ANSWER It is reduced back to the common +3 state.

SECTION I

Actinoids

Like lanthanoids, but radioactive and far more varied.

Feature	Lanthanoids (4f)	Actinoids (5f)
Oxidation states	Mainly +3 (+2, +4 occasionally)	+3 common, but up to +6 (U) and +7 (Np, Pu)
Why	4f is deeply buried	5f, 6d and 7s are close in energy; 5f extends further out
Contraction	Lanthanoid contraction	Actinoid contraction — larger from element to element (poorer 5f shielding)
Radioactivity	Only promethium	All radioactive
Complex formation	Weak	Stronger

SECTION J

Exam trap gallery

J

Where marks are lost in this chapter.

✗ TRAP 01 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Fe^{2+} is [Ar] $3d^4\ 4s^2$.	Fe^{2+} is [Ar] $3d^6$.
WHY 4s is filled first but also emptied first.	

✗ TRAP 02 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Zn is a transition element.	Zn is a d-block element but not a transition element.
WHY Zn and Zn^{2+} are both d^{10}.	

✗ TRAP 03 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Cu^+ is blue.	Cu^+ (d^{10}) is colourless; Cu^{2+} (d^9) is blue.
WHY No d–d transition is possible in d^0 or d^{10}.	

✗ TRAP 04 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
$KMnO_4$ is purple because of d–d transitions.	Mn in MnO_4^- is d^0; the colour is charge transfer (O → Mn).
WHY The same is true of orange dichromate (Cr +6, d^0).	

✗ TRAP 05 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
$KMnO_4$ in neutral solution gives Mn^{2+}.	Neutral or weakly alkaline: MnO_2 (3 e^-). Acidic: Mn^{2+} (5 e^-).
WHY Always check the medium before counting electrons.	

✗ TRAP 06 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Acidify $KMnO_4$ with HCl.	Use dilute H_2SO_4.
WHY HCl is oxidised to Cl_2, consuming permanganate.	

✗ TRAP 07 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Chromate → dichromate is a redox reaction.	It is an acid–base equilibrium; Cr stays +6.
WHY Only the pH changes.	

✗ TRAP 08 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Basicity of lanthanoid hydroxides increases from La to Lu.	It decreases: $La(OH)_3$ is the most basic.

WHY Smaller Ln^{3+} → more covalent M–OH bond.

✗ TRAP 09 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
The highest oxidation state in the d-block is +7 (Mn).	Os and Ru reach +8 (OsO_4).

WHY Mn has the most oxidation states in the 3d series, not the highest overall.

MEMORY HOOK

"**Four-s first in, four-s first out**" — ions lose 4s before 3d.

"**Acid five, neutral three, alkali one**" — electrons gained by MnO_4^- in each medium.

"**Fourteen H, six e, two Cr**" — $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+}$.

"**Zero or ten, no colour then**" — d^0 and d^{10} ions are colourless.

SECTION K

K

Practice MCQs

Levels: Easy, Moderate, Tough.

Q01 The electronic configuration of Cr is: [EASY]

(a) [Ar] $3d^4\ 4s^2$ (b) [Ar] $3d^5\ 4s^1$
(c) [Ar] $3d^6$ (d) [Ar] $3d^5\ 4s^2$

Q02 Which ion is colourless? [EASY]

(a) Ti^{3+} (b) V^{3+}
(c) Sc^{3+} (d) Cr^{3+}

Q03 Which 3d metal has a positive $E°(M^{2+}/M)$? [EASY]

(a) Fe (b) Zn
(c) Ni (d) Cu

Q04 The spin-only magnetic moment of Mn^{2+} is: [EASY]

(a) 3.87 BM (b) 4.90 BM
(c) 5.92 BM (d) 2.83 BM

Q05 In acidic medium, one MnO_4^- ion gains: [EASY]

(a) 1 electron (b) 3 electrons
(c) 5 electrons (d) 6 electrons

Q06 Which pair has almost the same atomic radius? [MODERATE]

(a) Ti and Zr
(b) Zr and Hf
(c) Sc and Y
(d) Cr and Mo

Q07 Of these 3d metals, the lowest melting point is shown by: [MODERATE]

(a) Cr
(b) V
(c) Fe
(d) Zn

Q08 $KMnO_4$ in neutral medium oxidises I^- to: [MODERATE]

(a) I_2
(b) IO_3^-
(c) IO_4^-
(d) IO^-

Q09 Moles of Fe^{2+} oxidised by one mole of $Cr_2O_7^{2-}$ in acid: [MODERATE]

(a) 3
(b) 5
(c) 6
(d) 7

Q10 Which statement about Cu^+ in water is correct? [MODERATE]

(a) It is stable
(b) It disproportionates to Cu and Cu^{2+}
(c) It is oxidised by air only
(d) It is coloured

Q11 Which is the strongest oxidising agent in water? [MODERATE]

(a) Cr^{3+}
(b) Mn^{3+}
(c) Fe^{3+}
(d) V^{3+}

Q12 The most basic hydroxide among these is: [MODERATE]

(a) $Lu(OH)_3$
(b) $Yb(OH)_3$
(c) $Gd(OH)_3$
(d) $La(OH)_3$

Q13 Which lanthanoid commonly shows +4 oxidation state? [TOUGH]

(a) Eu
(b) Yb
(c) Ce
(d) Gd

Q14 The colour of $KMnO_4$ is due to: [TOUGH]

(a) d–d transition
(b) f–f transition
(c) charge transfer from O to Mn
(d) unpaired electrons on Mn

Q15 An ion with μ = 2.83 BM could be: [TOUGH]

(a) Ti^{3+}
(b) Ni^{2+}
(c) Cr^{3+}
(d) Mn^{2+}

Answer key with explanations

Q01 **(b)** $[Ar]\ 3d^5\ 4s^1$ — Half-filled $3d^5$ is extra stable.

Q02 **(c)** Sc^{3+} — Sc^{3+} is d^0.

Q03 **(d)** **Cu** — Cu^{2+}/Cu = +0.34 V.

Q04 **(c) 5.92 BM** — d^5, five unpaired: $\sqrt{35}$.

Q05 **(c) 5 electrons** — +7 → +2.

Q06 **(b) Zr and Hf** — Lanthanoid contraction.

Q07 **(d) Zn** — Zn has no unpaired d electrons for metallic bonding.

Q08 **(b) IO_3^-** — Neutral/alkaline gives iodate; acidic gives I_2.

Q09 **(c) 6** — 6 electrons accepted per dichromate.

Q10 **(b) It disproportionates to Cu and Cu^{2+}** — Large hydration enthalpy of Cu^{2+}.

Q11 **(b) Mn^{3+}** — $Mn^{3+} \rightarrow Mn^{2+}$ gives stable d^5; E° = +1.57 V.

Q12 **(d) $La(OH)_3$** — Largest Ln^{3+} ion.

Q13 **(c) Ce** — Ce^{4+} is $4f^0$.

Q14 **(c) charge transfer from O to Mn** — Mn(+7) is d^0.

Q15 **(b) Ni^{2+}** — Ni^{2+} is d^8: two unpaired electrons.

Check-yourself answers

C1 Mn has a stable half-filled d^5 configuration, so fewer d electrons take part in metallic bonding.

C2 The lanthanoid contraction makes their radii almost identical (160 and 159 pm), so their chemistry is nearly the same.

C3 Cu^+ ($3d^{10}$).

C4 Three ($\sqrt{15}$ = 3.87).

QUICK REVISION

One-page revision

Read this page the night before the exam.

Configuration

- $(n-1)d^{1-10}\ ns^{1-2}$
- Cr $3d^5 4s^1$, Cu $3d^{10}4s^1$
- Ions lose 4s first: Fe^{2+} $3d^6$
- Zn, Cd, Hg: d-block, not transition

Trends

- Radius almost constant mid-series
- Mn mp dip; Zn lowest; W highest
- Zr ≈ Hf (lanthanoid contraction)
- Cu only positive E° (+0.34 V)

Oxidation states

- Mn most states (+2 to +7); Os +8
- High states with O and F
- Mn^{3+} oxidising, Cr^{2+} reducing
- Cu^{+} disproportionates in water

Colour and magnetism

- μ = √[n(n+2)]: 1.73, 2.83, 3.87, 4.90, 5.92
- d^0 / d^{10} colourless
- MnO_4^-, $Cr_2O_7^{2-}$ colour = charge transfer
- Catalysts: variable O.S. + surfaces

$KMnO_4$

- $MnO_2 + KOH + O_2 \rightarrow K_2MnO_4 \rightarrow KMnO_4$
- Acid $5e^- \rightarrow Mn^{2+}$; neutral $3e^- \rightarrow MnO_2$
- Strong alkali $1e^- \rightarrow MnO_4^{2-}$
- Acidify with H_2SO_4, never HCl

$K_2Cr_2O_7$ and f-block

- Chromite + Na_2CO_3 → chromate → dichromate
- $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+}$
- Ln: +3; Ce +4; Eu, Yb +2
- Actinoids: up to +7, all radioactive

END OF NOTES · RAMGOVINDYADAV.COM