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CHAPTER NOTES

The d- and f-Block Elements Class 12 Notes — CBSE Chemistry Chapter 8

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The d- and f-Block Elements Class 12 Notes — CBSE Chemistry Chapter 8

Chapter 8 — **The d- and f-Block Elements** — covers transition metals (3d, 4d, 5d series) and inner transition metals (lanthanoids and actinoids). These elements are known for their coloured compounds, variable oxidation states, and catalytic properties. This chapter carries **5-7 marks** in Board exams. Focus on properties of 3d series and preparation of $KMnO_4$ and $K_2Cr_2O_7$.

Key Concepts

d-Block Elements (Transition Elements)

General electronic configuration: $(n-1)d^{1\text{-}10}\ ns^{1\text{-}2}$

Characteristics of Transition Elements

Property	Explanation
Variable oxidation states	Due to involvement of both (n–1)d and ns electrons in bonding
Coloured compounds	Due to d-d transitions (unpaired d-electrons absorb visible light)
Complex formation	Small size + high charge + vacant d-orbitals accept lone pairs from ligands
Catalytic activity	Variable oxidation states + ability to form intermediates
Magnetic properties	Unpaired d-electrons → paramagnetic; all paired → diamagnetic
Alloy formation	Similar atomic sizes → atoms can substitute in crystal lattice
Interstitial compounds	Small atoms (H, C, N) fit in voids of metal lattice

Why Zn^{2+} compounds are colourless: Zn^{2+} has $3d^{10}$ — fully filled d-orbitals. No d-d transitions possible → no absorption of light → colourless! Same for Cu^{+} ($3d^{10}$) and Sc^{3+} ($3d^{0}$).

Electronic Configurations — Anomalies

Element	Expected	Actual	Reason
Cr (Z=24)	[Ar] $3d^4$ $4s^2$	[Ar] $3d^5$ $4s^1$	Half-filled d^5 is extra stable
Cu (Z=29)	[Ar] $3d^9$ $4s^2$	[Ar] $3d^{10}$ $4s^1$	Fully-filled d^{10} is extra stable

Oxidation States of 3d Series

Element	Common Oxidation States	Most Stable
Sc	+3	+3
Ti	+2, +3, **+4**	+4
V	+2, +3, +4, **+5**	+5
Cr	+2, **+3**, +6	+3
Mn	**+2**, +3, +4, +6, +7	+2
Fe	**+2**, **+3**	+2, +3
Co	**+2**, +3	+2
Ni	**+2**	+2
Cu	+1, **+2**	+2
Zn	**+2**	+2

Maximum oxidation state increases from Sc (+3) to Mn (+7), where it equals the total number of 3d + 4s electrons. After Mn, it decreases because electrons start pairing and d-electrons become too stable to lose.

Important Compounds

Potassium Permanganate ($KMnO_4$)

Preparation:

$2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4 + 2H_2O$ (fusion with KOH)

$3K_2MnO_4 + 2CO_2 \rightarrow 2KMnO_4 + MnO_2 + 2K_2CO_3$ (disproportionation)

Or electrolytically: $MnO_4^{2-} \rightarrow MnO_4^- + e^-$

Properties:

- Dark purple crystals, powerful oxidising agent
- **In acidic medium:** $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ (colourless)
- **In neutral/alkaline:** $MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$ (brown ppt)
- Used in titrations (self-indicator — purple → colourless)
- Oxidises Fe^{2+} to Fe^{3+}, oxalate to CO_2, SO_3^{2-} to SO_4^{2-}

Potassium Dichromate ($K_2Cr_2O_7$)

Preparation:

$4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$

$2Na_2CrO_4 + H_2SO_4 \rightarrow Na_2Cr_2O_7 + Na_2SO_4 + H_2O$

$Na_2Cr_2O_7 + 2KCl \rightarrow K_2Cr_2O_7 + 2NaCl$ (less soluble, crystallises)

Properties:

- Orange crystals, powerful oxidising agent in acidic medium
- **In acidic medium:** $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ (green)
- pH-dependent colour: CrO_4^{2-} (yellow, basic) $\rightleftharpoons$ $Cr_2O_7^{2-}$ (orange, acidic)
- Used in breathalyser test (turns green with alcohol)

Chromate-Dichromate Equilibrium:

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

Add acid → shifts right (orange) I Add base → shifts left (yellow)

f-Block Elements

Lanthanoids (4f series: Ce to Lu)

- General configuration: [Xe] $4f^{1-14}\ 5d^{0-1}\ 6s^2$
- **Common oxidation state: +3** (most stable). Some show +2 (Eu, Yb) and +4 (Ce, Tb)
- **Lanthanoid contraction:** Steady decrease in ionic radii from La^{3+} to Lu^{3+} due to poor shielding by 4f electrons
- Consequences of contraction: similar properties of 4d and 5d series elements in same group

Actinoids (5f series: Th to Lr)

- General configuration: [Rn] $5f^{1-14}$ $6d^{0-1}$ $7s^2$
- Show wider range of oxidation states than lanthanoids (+2 to +7)
- Most are radioactive; only Th, Pa, U occur naturally
- Also show contraction (actinoid contraction) similar to lanthanoids

Comparison: Lanthanoids vs Actinoids

Property	Lanthanoids	Actinoids
Filling orbitals	4f	5f
Oxidation states	Mainly +3	+2 to +7 (wider range)
Radioactivity	Not radioactive (except Pm)	All radioactive
Complex formation	Less tendency	Greater tendency
Contraction	Lanthanoid contraction	Actinoid contraction (greater)

Important Definitions

Term	Definition
Transition Element	Element with partially filled d-orbitals in its ground state or common ion
Lanthanoid Contraction	Gradual decrease in ionic radii across lanthanoid series due to poor 4f shielding
Interstitial Compound	Compound formed when small atoms (H, C, N) occupy voids in metal lattice
d-d Transition	Transition of electron between split d-orbitals responsible for colour

Solved Examples — NCERT Based

Example 1: Magnetic Moment

Q: Calculate the magnetic moment of Fe^{2+} and Fe^{3+}. Which is more paramagnetic?

Solution:

Fe^{2+} = [Ar] $3d^6$ → 4 unpaired electrons → $\mu = \sqrt{(4\times6)} = \sqrt{24}$ = **4.90 BM**

Fe^{3+} = [Ar] $3d^5$ → 5 unpaired electrons → $\mu = \sqrt{(5\times7)} = \sqrt{35}$ = **5.92 BM**

Fe^{3+} is **more paramagnetic** (higher magnetic moment due to more unpaired electrons).

Example 2: Colour of Transition Metal Ions

Q: Why are Zn^{2+} compounds colourless while Cu^{2+} compounds are blue?

Solution:

Zn^{2+} has configuration $3d^{10}$ — all d-orbitals are fully filled. No d-d transition is possible → **no visible light absorbed → colourless**.

Cu^{2+} has configuration $3d^9$ — one unpaired electron. d-d transition absorbs red light → **blue colour observed** (complementary colour).

Example 3: $KMnO_4$ as Oxidising Agent

Q: Write the ionic equation for the reaction of $KMnO_4$ with $FeSO_4$ in acidic medium.

Solution:

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ (reduction)

$Fe^{2+} \rightarrow Fe^{3+} + e^-$ (oxidation) × 5

Net: $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$

Purple $KMnO_4$ becomes colourless (Mn^{2+}), and pale green Fe^{2+} becomes yellow Fe^{3+}.

Example 4: Lanthanoid Contraction

Q: What is lanthanoid contraction? What are its consequences?

Solution:

Lanthanoid contraction is the gradual decrease in atomic/ionic radii from La to Lu due to poor shielding effect of 4f electrons.

Consequences:

1. Similarity in properties of 2nd and 3rd row transition metals (Zr/Hf, Nb/Ta, Mo/W have almost identical radii)
2. Difficulty in separating lanthanoids from each other
3. Basicity decreases from $La(OH)_3$ to $Lu(OH)_3$

Important Questions for Board Exams

1 Mark Questions

1. Why do transition metals show variable oxidation states?
2. Why is Zn not considered a transition element?
3. What causes the colour of transition metal compounds?
4. Calculate the magnetic moment of Mn^{2+}.

2 Mark Questions

1. Explain why Cr and Cu have anomalous electronic configurations.
2. What is lanthanoid contraction? Give two consequences.
3. Why is +2 the most stable oxidation state of Mn?
4. Write the chromate-dichromate equilibrium. What happens when acid is added?

3 Mark Questions

1. Describe the preparation and oxidising properties of $KMnO_4$ in acidic medium.
2. How is $K_2Cr_2O_7$ prepared from chromite ore? Write its action as an oxidising agent in acidic medium.
3. Compare lanthanoids and actinoids (any 5 differences).
4. Why do transition metals act as good catalysts? Give three examples.

5 Mark Questions

1. Discuss the general characteristics of transition elements: (a) variable oxidation states (b) colour (c) magnetic properties (d) catalytic activity (e) complex formation.
2. What is $KMnO_4$? How is it prepared? Write its reactions in (a) acidic medium (b) alkaline medium. Why is it called a self-indicator?

Quick Revision Points

- d-block: $(n-1)d^{1\text{-}10}\ ns^{1\text{-}2}$; Zn/Cd/Hg are NOT typical transition elements (d^{10})
- Anomalies: Cr = $[Ar]3d^5 4s^1$, Cu = $[Ar]3d^{10} 4s^1$
- Colour: due to d-d transitions; no colour if d^0 or d^{10}
- Magnetic moment: $\mu = \sqrt{n(n+2)}$ BM, where n = unpaired electrons
- $KMnO_4$: purple, self-indicator; acidic → Mn^{2+} (colourless); alkaline → MnO_2 (brown)
- $K_2Cr_2O_7$: orange in acid, yellow (CrO_4^{2-}) in base
- Lanthanoid contraction: poor 4f shielding → size decreases La to Lu
- Lanthanoids: mainly +3; Actinoids: +2 to +7, all radioactive
- Max oxidation state in 3d: increases Sc(+3) to Mn(+7), then decreases

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← Previous: p-Block Elements

Next: Coordination Compounds →