ANSWER KEY & MARKING SCHEME · CBSE CLASS 12

d- and f-Block Elements

Chemistry · Chapter 4 · Use this with the Board Paper · Companion to Quick Drill

HOW TO USE

Attempt the Board Paper first (closed-book, full time). Then come here. For 2-mark+ questions, compare your answer to the model. For 3-4 mark questions, also consult the **Topper Templates** below — these show the exact step-by-step structure that scores full marks per CBSE marking-scheme conventions.

MODEL ANSWERS · BOARD PAPER

Section A — Very Short Answer (1 mark each)

Q1. Why is Zn not regarded as a typical transition element? [1 mark]

Ans: Because both the Zn atom (3d10 4s2) and its common Zn^2+ ion (3d10) have a completely filled d-subshell, so there is no partially filled d-orbital.

Q2. Write the general electronic configuration of the d-block elements. [1 mark]

Ans: (n-1)d^1-10 ns^0-2.

Q3. Why is Sc^3+ colourless? [1 mark]

Ans: Sc^3+ has a 3d0 configuration (empty d-subshell), so no d-d transition is possible and it appears colourless.

Q4. Name the most common oxidation state of the lanthanides. [1 mark]

Ans: +3.

Section B — Short Answer I (2 marks each)

Q5. Calculate the spin-only magnetic moment of (i) Fe^2+ and (ii) Mn^2+ ions. (Atomic numbers: Fe=26, Mn=25) [2 marks]

Ans: (i) Fe^2+ = [Ar]3d6 with 4 unpaired electrons: mu = sqrt(4 x 6) = sqrt(24) = 4.90 BM. (ii) Mn^2+ = [Ar]3d5 with 5 unpaired electrons: mu = sqrt(5 x 7) = sqrt(35) = 5.92 BM.

Q6. Why do transition elements exhibit variable oxidation states? Illustrate with one example. [2 marks]

Ans: Because the (n-1)d and ns orbitals have very similar energies, a variable number of electrons from both subshells can participate in bonding. For example, manganese shows +2, +3, +4, +6 and +7 states.

Q7. Account for the following: (i) Transition metals form coloured ions. (ii) Transition metals are good catalysts. [2 marks]

Ans: (i) Ligands split the d-orbitals; an electron absorbs visible light and undergoes a d-d transition, so the ion shows the complementary colour. (ii) They have variable oxidation states (easy electron transfer) and large adsorbing surfaces that provide reaction sites, making them efficient catalysts.

Q8. Give two differences between lanthanides and actinides. [2 marks]

Ans: (1) Lanthanides are mostly limited to the +3 state, whereas actinides show a wide range up to +7 because 5f, 6d and 7s have comparable energies. (2) Most lanthanides are non-radioactive, while all actinides are radioactive.

Section C — Short Answer II (3 marks each)

Q9. What is lanthanide contraction? State its cause and any two consequences. [3 marks]

Ans: Lanthanide contraction is the steady decrease in atomic and ionic (M^3+) radii of the lanthanides with increasing atomic number from La (57) to Lu (71). Cause: as we move across, electrons enter the inner 4f subshell, which shields the outer electrons poorly, so the effective nuclear charge increases and the radius shrinks. Consequences: (1) Zr and Hf (and Nb-Ta) have nearly identical sizes and very similar chemistry, making their separation difficult; (2) the basic character of the hydroxides M(OH)3 decreases from La(OH)3 to Lu(OH)3.

Q10. **Write the ionic half-reactions for the reduction of MnO_4^- in (i) acidic, (ii) neutral, and (iii) strongly alkaline medium, with the oxidation-state change of Mn in each.** **[3 marks]**

> **Ans:** (i) Acidic: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ (Mn +7 to +2, 5-electron change). (ii) Neutral/faintly alkaline: $MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$ (Mn +7 to +4, 3-electron change). (iii) Strongly alkaline: $MnO_4^- + e^- \rightarrow MnO_4^{2-}$ (Mn +7 to +6, 1-electron change).

Q11. **Describe the preparation of potassium dichromate from chromite ore, giving balanced equations for the main steps.** **[3 marks]**

> **Ans:** Step 1 (fusion with alkali in air): $4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$, giving yellow sodium chromate. Step 2 (acidification): $2Na_2CrO_4 + 2H^+ \rightarrow Na_2Cr_2O_7 + 2Na^+ + H_2O$, giving orange sodium dichromate (chromate-dichromate equilibrium). Step 3 (conversion to potassium salt): $Na_2Cr_2O_7 + 2KCl \rightarrow K_2Cr_2O_7 + 2NaCl$; the less soluble $K_2Cr_2O_7$ crystallises on cooling.

Q12. **Account for the following: (i) $E^0(Mn^{3+}/Mn^{2+})$ is much more positive than $E^0(Cr^{3+}/Cr^{2+})$. (ii) The highest oxidation state of a transition metal is shown in its oxide or fluoride. (iii) Transition metals form a large number of interstitial compounds.** **[3 marks]**

> **Ans:** (i) Mn^{2+} has a stable half-filled $3d^5$ configuration, so reducing Mn^{3+} to Mn^{2+} is highly favourable, making $E^0(Mn^{3+}/Mn^{2+})$ strongly positive; Cr^{2+} ($3d^4$) has no such stability. (ii) Oxygen and fluorine are the most electronegative and small, able to stabilise the highest oxidation states through strong bonding (e.g. MnO_4^-, CrF_6). (iii) Small non-metal atoms (H, C, N, B) occupy the interstitial holes of the metal lattice, giving hard, high-melting, inert interstitial compounds.

Section D — Long Answer (6 marks)

Q13. **(a) Explain why (i) the melting points of transition metals first rise and then fall across a series, and (ii) the enthalpies of atomisation are high for transition metals. (3 marks) (b) Calculate the spin-only magnetic moments of Cr^{3+} (Z=24), Co^{2+} (Z=27) and Cu^{2+} (Z=29) and state whether each is paramagnetic. (3 marks)** **[6 marks]**

> **Ans:** (a) (i) Melting point depends on the strength of metallic bonding, which increases with the number of unpaired d-electrons available for bonding. This number rises to a maximum near the middle of the series (d^5 region) and then falls, so the melting point first rises and then falls (Mn dips owing to the stable half-filled d^5; Zn is low with filled d^{10}). (ii) Transition metals have many unpaired d-electrons forming strong metallic bonds, so a large amount of energy is needed to atomise them, giving high enthalpies of atomisation. (b) Cr^{3+} = [Ar]$3d^3$, n=3: $\mu = \sqrt{3 \times 5} = 3.87$ BM. Co^{2+} = [Ar]$3d^7$, n=3: $\mu = \sqrt{3 \times 5} = 3.87$ BM. Cu^{2+} = [Ar]$3d^9$, n=1: $\mu = \sqrt{1 \times 3} = 1.73$ BM. All three have unpaired electrons, so all are paramagnetic.

★ TOPPER ANSWER TEMPLATES

5 TEMPLATES · MEMORISE THE FORMAT

MARKING SCHEME — GENERAL NOTES

- Award full marks for any correct alternative method or valid reasoning.
- For magnetic-moment numericals, 50% weight is on the correct ion configuration and unpaired-electron count, 50% on the mu value with unit BM.
- Deduct 0.5 mark if the unit BM is missing on a final magnetic-moment answer.
- For redox half-reactions, award marks only if both charge and atoms are balanced and the oxidation-state change is shown.
- Accept either CrO_4^{2-} or $Cr_2O_7^{2-}$ forms in the chromate-dichromate equilibrium provided the colour and pH dependence are stated.
- For 'account for' questions, the explanation (not the statement) carries the marks; mere restatement earns zero.
- In the lanthanide-contraction question, both the definition (decrease in size) and the cause (poor 4f shielding) must appear for full marks.