CHEMISTRY (CODE – 043)

Chapter-wise Test: The d- and f-Block Elements

(NCERT Class XII Chemistry, Unit 4: The d- and f-Block Elements)

SOLUTIONS AND MARKING SCHEME

CLASS XII (2026-27)

Time: 1½ hours **Max. Marks: 35**

Step-by-step solutions with the distribution of marks. Marks for each step are shown in square brackets [ ]. Any other correct method or answer should be given full credit.

Quick answer key – Section A

Q.	1	2	3	4	5	6	7	8
Ans.	C	B	D	C	A	B	C	A

SECTION A

Questions 1 to 8 are multiple choice questions. Only one of the choices is correct. Select and write the correct choice as well as the answer to these questions. Each question carries 1 mark.

1	**Answer: C. Zn** A transition element has an incomplete d subshell either in its ground state or in its common oxidation states. Zn ($3d^{10}4s^2$) has a completely filled d subshell in the ground state and in its only common oxidation state, Zn^{2+} ($3d^{10}$), so it is not a transition element. Cu is a transition element because Cu^{2+} has the $3d^9$ configuration.	1
2	**Answer: B** The negative $E°$ (−0.41 V) of Cr^{3+}/Cr^{2+} means Cr^{3+} is very stable (d^3, $t_{2g}^{\ 3}$ configuration) and Cr^{2+} readily loses an electron, i.e. Cr^{2+} is a strong reducing agent. The large positive $E°$ (+1.57 V) of Mn^{3+}/Mn^{2+} shows that Mn^{2+} (d^5, half-filled) is very stable, so Mn^{3+} readily accepts an electron and is a strong oxidising agent. A is wrong (1.57 > 0.77), D is wrong (Cr^{3+} is not easily reduced).	1
3	**Answer: D** The enthalpy of atomisation depends on the strength of metallic bonding, which increases with the number of unpaired d electrons that take part in bonding. Zinc has the $3d^{10}4s^2$ configuration with no unpaired d electrons, so only the weak interatomic interaction of the 4s electrons operates and $\Delta_a H°$ is the lowest (126 kJ mol^{-1}). The peak at V (515 kJ mol^{-1}) corresponds to the largest number of unpaired d electrons available for bonding.	1
4	**Answer: C. 5.92** Mn^{2+} has the configuration $3d^5$ with $n = 5$ unpaired electrons. $\mu = \sqrt{[n(n+2)]} = \sqrt{(5 \times 7)} = \sqrt{35} =$ **5.92 BM**.	1
5	**Answer: A** In the lanthanoids the extra electron enters the inner 4*f* subshell. The shielding of one 4*f* electron by another is very poor, so the effective nuclear charge increases with atomic number and the atomic and ionic radii decrease steadily from La to Lu (lanthanoid contraction).	1
6	**Answer: B. Mn^{2+}** In acidic solution: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ ($E° = +1.52$ V). In neutral or faintly alkaline solution the product is MnO_2, and in strongly alkaline solution it is MnO_4^{2-}.	1
7	**Answer: C. MnO_4^- and MnO_2** $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$. Mn(VI) is simultaneously oxidised to Mn(VII) (purple permanganate) and reduced to Mn(IV) (brown MnO_2).	1

8	**Answer: A. Both A and R are true, and R is the correct explanation of A.** $2Cu^{+}(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$. The high negative hydration enthalpy of $Cu^{2+}(aq)$ more than compensates for the energy needed for the second ionisation of Cu, so Cu(II) is the stable state in aqueous solution and Cu(I) disproportionates.	1

SECTION B

Question Nos. 9 to 11 are very short answer questions carrying 2 marks each.

9	**(A)** (i) Sc^{3+} ($3d^0$) has no electron in the d orbitals and Zn^{2+} ($3d^{10}$) has completely filled d orbitals. No d–d transition is possible in either, so they do not absorb visible light and are colourless. [1] (ii) Each of them has a partially filled d subshell. An electron from a lower energy d orbital is excited to a higher energy d orbital (d–d transition) by absorbing light of a certain frequency in the visible region; the colour observed is the complementary colour of the light absorbed. [1] **(B)** (i) Cu^{+} has the configuration $3d^{10}$ (completely filled d orbitals), so no d–d transition is possible and the ion is **colourless**. [1] (ii) $Mn^{2+} = 3d^5$, $n = 5$. $\mu = \sqrt{[n(n+2)]} = \sqrt{35} =$ **5.92 BM** [1]	1 + 1
10	**(A)** Cr: [Ar] $3d^5 4s^1$; Cu: [Ar] $3d^{10} 4s^1$ [1] The expected configurations $3d^4 4s^2$ and $3d^9 4s^2$ are not obtained because a half-filled (d^5) and a completely filled (d^{10}) d subshell have extra stability (symmetrical distribution and exchange energy), so one 4s electron shifts to the 3d orbital. [1] **(B)** (i) Compounds formed when small atoms such as H, C or N are trapped in the interstitial voids (vacant spaces) of the crystal lattices of metals, e.g. TiC, Fe_3H, Mn_4N. [1] (ii) They are very hard, have high melting points (higher than those of the pure metals), retain metallic conductivity and are chemically inert. (Any two) [1]	1 + 1
11	**(A)** (i) $Co^{2+} = 3d^7 \rightarrow$ 3 unpaired electrons. $\mu = \sqrt{[3 \times 5]} = \sqrt{15} =$ **3.87 BM** [1] (ii) $Ni^{2+} = 3d^8 \rightarrow$ 2 unpaired electrons. $\mu = \sqrt{[2 \times 4]} = \sqrt{8} =$ **2.83 BM** [1] **(B)** (i) $Cr_2O_7^{2-} + 14H^{+} + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$ [1] (ii) $Cr_2O_7^{2-} + 14H^{+} + 6I^{-} \rightarrow 2Cr^{3+} + 3I_2 + 7H_2O$ [1]	1 + 1

SECTION C

Question Nos. 12 to 15 are short answer questions carrying 3 marks each.

12	**(A)** (i) **Manganese** (+2 to +7). Mn has five unpaired d electrons ($3d^5 4s^2$) and both the 4s and the 3d electrons, whose energies are close, can take part in bonding. [1] (ii) Sc ($3d^1 4s^2$) has too few electrons: after losing all three it reaches the noble gas configuration, so only +3 is shown. Zn ($3d^{10} 4s^2$) has a completely filled d subshell, so only the two 4s electrons are lost (+2). [1] (iii) $2Cu^+(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$ (disproportionation). The very high negative hydration enthalpy of $Cu^{2+}(aq)$ more than compensates for the second ionisation enthalpy, so Cu(II) is more stable than Cu(I) in water. [1] **(B)** (i) Cr^{2+} (d^4) changes to Cr^{3+} (d^3, stable t_{2g}^3 configuration), so it readily loses an electron. Mn^{3+} (d^4) changes to Mn^{2+} (d^5, half-filled, extra stable), so it readily gains an electron. [1] (ii) They show variable oxidation states and can form unstable intermediate compounds (or provide a large surface area for the reactants to be adsorbed), giving an alternative path of lower activation energy. [1] (iii) The metal ions are small with a high charge, have vacant d orbitals to accept lone pairs from ligands and have comparatively high ionic charge density. [1]	1 + 1 + 1
13	**(A)** (i) The radii decrease steadily from La^{3+} (106 pm) to Yb^{3+} (86 pm). The phenomenon is called the **lanthanoid contraction**. [1] (ii) The additional electron enters the 4*f* subshell; the shielding of one 4*f* electron by another is very poor, so the effective nuclear charge increases from element to element and pulls the outer electrons inward. [1] (iii) The radii of the 5d (third series) elements become very similar to those of the corresponding 4d (second series) elements (e.g. Zr 160 pm, Hf 159 pm), so they have very similar properties, occur together in nature and are very difficult to separate. [1] **(B)** (i) Ce^{4+} has the noble gas configuration ($4f^0$) but is more stable as Ce^{3+}, so it accepts an electron easily and is a good oxidising agent ($E° = +1.74$ V). Eu^{2+} ($4f^7$) changes to the common, more stable +3 state by losing an electron, so it is a good reducing agent. [1] (ii) Mischmetall is an alloy consisting of a lanthanoid metal (≈ 95%), iron (≈ 5%) and traces of S, C, Ca and Al. It is used in Mg-based alloys to produce bullets, shell and lighter flint. [1 + 1 for composition and use; ½ each acceptable]	1 + 1 + 1
14	**(A)** (i) **A = Na_2CrO_4** (sodium chromate, yellow), **B = $Na_2Cr_2O_7$** (sodium dichromate, orange), **C = $K_2Cr_2O_7$** (potassium dichromate). Step I: $4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$; $Na_2Cr_2O_7 + 2KCl \rightarrow K_2Cr_2O_7 + 2NaCl$. [1] (ii) $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ [1] (iii) The orange colour changes to yellow because dichromate is converted into chromate in alkaline medium: $Cr_2O_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$ [1] **(B)** (i) $5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$ [1] (ii) $5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$ [1] (iii) $10I^- + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 8H_2O + 5I_2$ [1]	1 + 1 + 1

15	**(A)** Step 1: MnO_2 is fused with KOH in the presence of air or KNO_3 (an oxidising agent) to give dark green potassium manganate: $2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4 + 2H_2O$ [1] Step 2: the manganate disproportionates in neutral or acidic solution: $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$ [1] Commercially, the manganate formed in alkaline fusion is converted to permanganate by **electrolytic oxidation** in alkaline solution: $MnO_4^{2-} \rightarrow MnO_4^- + e^-$. [1] **(B)** Any three differences (1 mark each): • Lanthanoids show mainly the +3 oxidation state (+2 and +4 occasionally); actinoids show a much wider range of oxidation states (+3 to +7). • Lanthanoids (except Pm) are non-radioactive; all actinoids are radioactive. • In lanthanoids the 4*f* electrons are deeply buried and have a very small effect on the properties; the 5*f* orbitals of actinoids extend farther and take part in bonding, so actinoid chemistry is more complex. • The actinoid contraction is greater from element to element than the lanthanoid contraction because of the poorer shielding by 5*f* electrons. • Actinoids form complexes more readily than lanthanoids.	1 + 1 + 1

SECTION D

Question No. 16 is a case-based/data-based question carrying 4 marks.

16	(i) Copper: 339 + 745 + 1958 − 2121 = **+921 kJ mol^{-1}**. Zinc: 130 + 906 + 1734 − 2059 = **+711 kJ mol^{-1}**. [1] (ii) **Copper** is the weakest reducing agent: the energy needed to form $Cu^{2+}(aq)$ (+921 kJ mol^{-1}) is the largest, because its hydration enthalpy does not balance the large $\Delta_a H°$ and ionisation enthalpies. Hence its $E°$ is positive (+0.34 V). Since $E°$ (Cu^{2+}/Cu) > 0, Cu cannot liberate hydrogen from dilute acids. [1] (iii) **(A)** Mn^{2+} has the stable half-filled $3d^5$ configuration, so Mn is oxidised to Mn^{2+} very easily (the sum of the energy terms is the lowest, +643 kJ mol^{-1}), making $E°$ more negative. [2] **(B)** Ni^{2+} has the highest negative hydration enthalpy in the series (−2121 kJ mol^{-1}, because of its small size), which offsets the energy needed for atomisation and ionisation, so Ni is a weaker reducing agent than expected and its $E°$ (−0.25 V) is less negative. [2]	1 + 1 + 2

SECTION E

Question No. 17 is a long answer question carrying 5 marks.

17	**(A)** (i) **A = K_2MnO_4** (potassium manganate, green), **B = $KMnO_4$** (potassium permanganate, purple), **C = MnO_2** (brown), **D = O_2**. [2: ½ each] (ii) $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$ [1] (iii) $2KMnO_4 \rightarrow$(513 K) $K_2MnO_4 + MnO_2 + O_2$ [1] (iv) The manganate ion MnO_4^{2-} has Mn(VI), $3d^1$, one unpaired electron, so it is paramagnetic. The permanganate ion MnO_4^- has Mn(VII), $3d^0$, no unpaired electrons, so it is diamagnetic. [1] **(B)** (1 mark each) (i) The (n−1)d and ns electrons have nearly the same energy, so both can take part in bonding; incomplete filling of d orbitals gives oxidation states that differ by unity (e.g. V^{II}, V^{III}, V^{IV}, V^{V}). [1] (ii) Partially filled d orbitals allow d–d transitions: light of a certain frequency in the visible region is absorbed and the complementary colour is seen. [1] (iii) They show variable oxidation states and can form unstable intermediate compounds, giving an alternative path of lower activation energy; they also provide a large surface area for adsorption of reactants (e.g. V_2O_5 in the contact process, Fe in the Haber process). [1] (iv) Small atoms (H, C, N) get trapped in the vacant interstitial spaces of the metal lattices, forming hard, high melting interstitial compounds. [1] (v) A large number of unpaired d electrons take part in strong metallic bonding between atoms, so a lot of energy is needed to atomise them. [1]	5

Topic coverage of the paper

Topic (NCERT section)	Questions
Position, electronic configuration, general trends of d-block (4.1–4.3)	Q1, Q3 (graph), Q10, Q17 (B)
Oxidation states and electrode potentials (4.3.4–4.3.8)	Q2 (table), Q8, Q12 (table), Q16 (table)
Magnetic properties and coloured ions (4.3.9, 4.3.10)	Q4, Q9 (table), Q11 (A), Q17 (B)
Catalytic property, interstitial compounds, alloys (4.3.12–4.3.14)	Q10 (B), Q12 (B), Q17 (B)
Potassium dichromate and potassium permanganate (4.4)	Q6, Q7, Q11 (B), Q14 (figure), Q15 (A), Q17 (A)
Lanthanoids and actinoids (4.5, 4.6)	Q5, Q13 (table), Q15 (B)

Figure/table-based questions (7): Q2, Q3, Q9, Q12, Q13, Q14 and Q16.