Ch-4 d and f block elements (Previous years Questions)

CBSE 2015

1. Write one similarity and one difference between the chemistry of lanthanoids and that of actinoids. [2015] 2

Ans. **Similarity**

Lanthanoids show lanthanoid contraction like actinoids contraction.

Dissimilarity

Lanthanoids show mostly +3 oxidation state. Few show +2 and +4, whereas Actinoids show +3, +4, +5, +6 and +7 oxidation state.

2 (*a*) Account for the following: [CBSE 2015]

(*i*) Cu^+ is unstable in an aqueous solution.

(*ii*) Transition metals form complex compounds.

(*b*) Complete the following equation:

$Cr_2O_7^{2-} + 8H^+ + 3NO_2^- \rightarrow$ 3

Ans. (*a*) (*i*) It is because hydration energy of Cu^{2+} overcomes 2nd ionisation enthalpy that is why Cu^+ changes to Cu^{2+} and Cu.

$$2Cu^+ \longrightarrow Cu^{2+} + Cu$$

(*ii*) It is due to small size, high charge and availability of vacant *d*-orbitals.

(*b*) $6e^- + 14H^+ + Cr_2O_7^{2-} \longrightarrow 2Cr^{3+} + 7H_2O$ ...(i)

$[H_2O + NO_2^- \longrightarrow NO_3^- + 2H^+ + 2e^-] \times 3$ ...(ii)

$8H^+ + Cr_2O_7^{2-} + 3NO_2^- \longrightarrow 2Cr^{3+} + 4H_2O + 3NO_3^-$ Adding (i) and (ii) we get

CBSE 2016

1 **(*a*) Account for the following:** CBSE-2016

(*i*) Mn_2O_7 is acidic whereas MnO is basic.

(*ii*) Though copper has completely filled *d*-orbital (d^{10}) yet it is considered as a transition metal.

(*iii*) Actinoids show wide range of oxidation states.

(*b*) Write the preparation of potassium permanganate from pyrolusite ore (MnO_2). **[5]**

Ans. (*a*) (*i*) It is because of higher oxidation +7 in Mn_2O_7 than +2 in MnO.

(*ii*) It is due to presence of unpaired electron in 3*d* orbital in its +2 oxidation state.

(*iii*) It is because 5*f*, 6*d* and 7*s* orbitals.

(*b*) $2MnO_2 + 4KOH + O_2 \longrightarrow 2K_2MnO_4 + 2H_2O$

$3MnO_4^{2-} + 4H^+ \longrightarrow 2MnO_4^- + MnO_2 + 2H_2O$

or $MnO_4^{2-} \xrightarrow{\text{electrolysis}} MnO_4^- + e^-$

Or

(*a*) The elements of 3*d* transition series are given as:

Sc Ti V Cr Mn Fe Co Ni Cu Zn

Answer the following:

(*i*) Which element has the highest m.p. and why?

(*ii*) Which element is a strong oxidizing agent in +3 oxidation state and why?

(*iii*) Which element is soft and why?

(*b*) Write the equation involved in the preparation of Potassium dichromate from Sodium chromate (Na_2CrO_4).

Or

Ans (*a*) (*i*) Cr. It is due to presence of maximum number of electrons forming strong metallic bonds.

(*ii*) Mn^{3+} is a strong oxidising agent because it can gain one electron to form Mn^{2+} which is more stable due to half-field *d*-orbital.

(*iii*) Zn, because it does not have unpaired electron and has weak metallic bonds.

(*b*) $2Na_2CrO_4 + H_2SO_4 \longrightarrow Na_2Cr_2O_7 + Na_2SO_4 + H_2O$

$Na_2Cr_2O_7 + 2KCl \longrightarrow K_2Cr_2O_7 + 2NaCl$

CBSE 2017

(*a*) Account for the following: [CBSE-2017]

(*i*) Transition metals show variable oxidation states.

(*ii*) Zn, Cd and Hg are soft metals.

(*iii*) E° value for the Mn^{3+}/Mn^{2+} couple is highly positive (+ 1.57 V) as compared to Cr^{3+}/Cr^{2+}.

(*b*) Write one similarity and one difference between the chemistry of lanthanoid and actinoid elements. **[5]**

Ans. (*a*) (*i*) It is because electrons from both *s* and *d*-orbitals take part in bond formation. e.g. Mn has outer electronic configuration $4s^2 3d^5$, it shows +2 +3, +4, +6, +7 oxidation state due to participation of both 4*d* and 3*d* electrons.

(*ii*) It is because of weak metallic bond due to absence of unpaired electrons. Unpaired electrons form additional $d\pi$-$d\pi$ (*pi*, π) bond which is not possible in Zn, Cd, Hg. It is also due to large size of their atoms due to which metallic bond is weak.

(*iii*) It is because Mn^{2+} is more stable than Cr^{2+} due to half filled ($3d^5$) orbitals. Half filled orbitals ($3d^5$) is more stable than $3d^4$ in Cr^{2+}.

(*b*) Similarity

(*i*) In both *f*-orbital is progressively filled

(*ii*) Both show contraction in atomic and ionic size.

(*iii*) In both +3 most stable oxidation state. (*any one*)

Differences

(*i*) All actinoids are radioactive, only one lanthanoid is radioactive

(*ii*) Actinoids show +3, +4, +5, +6, +7 oxidation state where as lanthanoid show +2, +3, +4 oxidation states only. (*any one*)

Or

(*a*) Following are the transition metal ions of 3d series:

Ti^{4+}, V^{2+}, Mn^{3+}, Cr^{3+}

(Atomic numbers: Ti = 22, V = 23, Mn = 25, Cr = 24)

Answer the following:

(*i*) Which ion is most stable in an aqueous solution and why?

(*ii*) Which ion is a strong oxidising agent and why?

(*iii*) Which ion is colourless and why?

(*b*) Complete the following equations:

(*i*) $2MnO_4^- + 16H^+ + 5S^{2-} \longrightarrow$

(*ii*) $KMnO_4 \xrightarrow{\text{heat}}$

Or

Ans. (*a*) (*i*) Cr^{3+} is most stable in aqueous solution due to half filled t_{2g}^3 orbital, smaller size and high hydration enthalpy.

(*ii*) Mn^{3+} is strong oxidising agent because it can one electrons to form Mn^{2+} when is more stable ($3d^5$).

(*iii*) Ti^{4+} is colourless because it does not have unpaired electrons and cannot undergo *d*-*d* transitions.

(*b*) (*i*) $2MnO_4^- + 16\ H^+ + 5\ s^{2-} \longrightarrow 2Mn^{2+} + 8H_2O + 5\ s$

(*ii*) $2KMnO_4 \xrightarrow{\text{Heat}} K_2MnO_4 + MnO_2 + O_2$

CBSE 2018

1. **Complete and balance the following chemical equations:**

(*a*) $Fe^{2+} + MnO_4^- + H^+ \longrightarrow$ CBSE -2018

(*b*) $MnO_4^- + H_2O + I^- \longrightarrow$

Ans (*a*) $5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$

(*b*) $2MnO_4 + H_2O + I^- \longrightarrow 2MnO_2 + 2OH^- + IO_3^-$

2. **Give reasons:**

(*a*) **E^0 value for Mn^{3+}/Mn^{2+} couple is much more positive than that for Fe^{3+}/Fe^{2+}**

(*b*) **Iron has higher enthalpy of atomization than that of copper.**

(*c*) **Sc^{3+} is colourless in aqueous solution whereas Ti^{3+} is coloured.**

Ans (*a*) It is because $Mn^{2+}(3d^5)$ is more stable than $Mn^{3+}(3d^4)$, and 3rd I.E is high, high energy is needed to convert Mn^{2+} to Mn^{3+}.

(*b*) It is because iron has large number of unpaired electrons in *d*-orbitals and form stronger metallic bond than 'Cu' which has completely filled *d*-orbital $(3d^{10})$ and hence enthalpy of atomization is higher than that of copper.

(*c*) Sc^{3+} does not have unpaired electron whereas Ti^{3+} has one unpaired electron, it can undergo *d-d* transition by absorbing light from visible region and radiate complementary colour.

CBSE 2019

1. **When MnO_2 is fused with KOH in the presence of KNO_3 as an oxidizing agent, it gives a dark green compound (A). Compound (A) disproportionates in acidic solution to give purple compound (B). An alkaline solution of compound (B) oxidises KI to compound (C) whereas an acidified solution of compound (B) oxidises KI to (D). Identify (A), (B), (C) and (D).** CBSE-2019

Ans. 'A' is potassium manganate (K_2MnO_4), 'B' is potassium permanganate ($KMnO_4$), 'C' is potassium iodate (KIO_3) and 'D' is molecular iodine.

$$2MnO_2 + 4KOH + O_2 \longrightarrow \underset{\text{'A'}}{2K_2MnO_4} + 2H_2O$$

(Dark green solution)

K_2MnO_4 gives MnO_4^{2-} ions which undergoes oxidation as well as reduction (disproportionation) into MnO_4^- and MnO_2.

$$\underset{\text{'B'}}{3MnO_4^{2-}} + 4H^+ \longrightarrow \underset{\text{'B'}}{3MnO_4^-} + MnO_2 + 2H_2O$$

Purple

Purple coloured $KMnO_4$ 'C' gives MnO_4^- ions which convert KI to KIO_3 in basic medium and 'A' (MnO_2) is also formed.

$$\underset{\text{'B'}}{2MnO_4^-} + H_2O + KI \longrightarrow 2MnO_2 + 2OH^- + \underset{\substack{\text{'C'}\\ \text{Potassium}\\ \text{iodate}}}{KIO_3}$$

In acidic medium, the iodide ion will oxidise to molecular iodine.

$$2MnO_4^- + 10\ I^- + 16\ H^+ \longrightarrow 2Mn^{2+} + \underset{\text{'D'}}{5I_2} + 8H_2O$$

CBSE 2020

1. (*a*) **Give reasons:**

(*i*) **Transition metals and their compounds show catalytic activities.** CBSE-2020

(*ii*) **Separation of a mixture of Lanthanoid elements is difficult.**

(*iii*) **Zn, Cd and Hg are soft and have low melting point.**

(*b*) **Write the preparation of the following:**

(*i*) **$Na_2Cr_2O_7$ from Na_2CrO_4**

(*ii*) **K_2MnO_4 from MnO_2** **3+2=5**

Ans. (*a*) (*i*) It is because they show variable oxidation states and have vacant *d*-orbitals forming unstable intermediates which readily change into products.

(*ii*) It is due to similar ionic size, similar properties due to lanthanoid contraction, their separation is difficult.

(*iii*) It is because they have weak metallic bonds due to absence of unpaired electrons.

(*b*) (*i*) $2Na_2CrO_4 + H_2SO_4\,(conc.) \longrightarrow Na_2Cr_2O_7 + Na_2SO_4 + H_2O$

(*ii*) $2MnO_2 + 4KOH + O_2 \longrightarrow 2K_2MnO_4 + 2H_2O$

[Balancing may be ignored while awarding marks.]

2. (*a*) **Account for the following:**

(*i*) **Ti^{3+} is coloured whereas Sc^{3+} is colourless in aqueous solution.**

(*ii*) **Cr^{2+} is a strong reducing agent.**

(*b*) **Write two similarities between chemistry of lanthanoids and actinoids.**

(*c*) **Complete the following ionic equation:** **2+2+1=5**

$3MnO_4^{2-} + 4H^+ \longrightarrow$

Ans. (*a*) (*i*) Ti^{3+} has one unpaired electron and undergoes *d-d* transitions by absorbing visible light and radiates violet colour, Sc^{3+} does not have unpaired electrons.

(*ii*) Cr^{2+} is stronger reducing agent because it will get oxidised to Cr^{3+} which has half-filled t_{2g}^3 which is more stable than $3d^5$ in Fe^{3+}.

(*b*) **Similarity:** (*i*) Both lanthanoids and actinoids show contraction.

(*ii*) The most characteristic oxidation state of both lanthanoid and actinoid is +3.

(*iii*) Both show variable oxidation state.

(*iv*) Both show *f-f* transition.

(*v*) electrons of *f*-orbitals in both have poor shielding effect. (*Any two*)

(*c*) $3MnO_4^{2-} + 4H^+ \longrightarrow 3MnO_4^- + MnO_2 + 2H_2O$

CBSE 2021

1. Following ions of 3d-transition series are given : CBSE - 2021

Ti^{4+}, V^{3+}, Cr^{3+}, Mn^{3+}

(Atomic number : Ti = 22, V = 23, Cr = 24, Mn = 25)

Identify the ion which is

(i) most stable in aqueous solution.

(ii) a strong oxidising agent.

(iii) colourless in aqueous solution.

Give suitable reason in each. **1 × 3 = 3**

Ans.

(i)	Cr^{3+}, due to stable t_{2g}^3 configuration.	½+½
(ii)	Mn^{3+}, as Mn is more stable in +2 oxidation state / stable half-filled d^5 configuration of Mn^{2+}.	½+½
(iii)	Ti^{4+}, no unpaired electrons / no d-d transition / d^0 configuration.	½+½

2. (a) Account for the following :

(i) Transition elements have higher enthalpies of atomisation.

(ii) Separation of a mixture of Lanthanoid elements is difficult.

(iii) The $E^\circ_{M^{2+}/M}$ value for copper is positive. **1 × 3 = 3**

Ans.

(a)(i) Because of greater number of unpaired electrons which cause strong metallic bonding / strong interatomic interaction forces.	1
(ii) Because of lanthanoid contraction / similar atomic or ionic radii / similar properties.	1
(iii) Because of high ΔaH° and low $\Delta_{hyd}H^\circ$	1

OR

3. (b) Define transition elements. Which of the d-block elements may not be regarded as the transition elements ? Why transition metals generally form coloured compounds ? **3**

Ans.

OR	
(b) The elements with partially filled or incompletely filled d-subshell either in the ground state or in the oxidation state.	1
Zinc, cadmium and mercury are not considered as transition elements.	1
Due to d-d transition or presence of unpaired d electrons.	1

CBSE 2023

1. The most common and stable oxidation state of a Lanthanoid is : CBSE-2023

(a) + 2 (b) + 3

(c) + 4 (d) + 6

2. Complete the following equations :

(a) $2MnO_4^- + 5NO_2^- + 6H^+ \longrightarrow$

(b) $Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow$

Ans 2

(a) $2\,MnO_4^- + 5\,NO_2^- + 6\,H^+ \longrightarrow 2\,Mn^{2+} + 5\,NO_3^- + 3\,H_2O$	1
(b) $Cr_2O_7^{2-} + 14\,H^+ + 6\,e^- \longrightarrow 2\,Cr^{3+} + 7\,H_2O$	1

3. Assign reason for each of the following : $5\times1=5$

(i) Manganese exhibits the highest oxidation state of +7 among the 3d series of transition elements.

(ii) Transition metals and their compounds are generally found to be good catalysts in chemical reactions.

(iii) Cr^{2+} is reducing in nature while with the same d-orbital configuration (d^4) Mn^{3+} is an oxidising agent.

(iv) Zn has lowest enthalpy of atomization.

(v) Cu^+ is unstable in an aqueous solution.

Ans 3

(i) Due to the participation of all 3d and 4s electrons in bond formation /due to the presence of maximum number of unpaired electrons.	1
(ii) Due to variable oxidation state / due to the ability to adopt multiple oxidation states / due to the large surface area / due to complex formation.	1
(iii) Cr^{2+} changes from d^4 to stable half-filled t_{2g}^3 configuration while Mn^{3+} changes to stable half-filled d^5 configuration.	1
(iv) Due to the absence of unpaired electrons and weak interatomic interactions.	1
(v) Cu^+ ion (aq.) undergoes disproportionation to Cu^{2+} (aq.) and Cu / $2\,Cu^+(aq.) \longrightarrow Cu^{2+}(aq.) + Cu(s)$	1

4. Which one among the following metals of 3*d* series has the lowest melting point?

(*a*) Fe (*b*) Mn (*c*) Zn (*d*) Cu

5. **Assertion (A):** Transition metals have high enthalpy of atomisation.

Reason (R): Greater number of unpaired electrons in transition metals results in weak metallic bonding.

6. (*a*) **I.** Account for the following: **3+2**

(*i*) E° value for Mn^{3+}/Mn^{2+} couple is much more positive than that for Cr^{3+}/Cr^{2+}.

(*ii*) Sc^{3+} is colourless whereas Ti^{3+} is coloured in an aqueous solution.

(*iii*) Actinoids show wide range of oxidation states.

II. Write the chemical equations for the preparation of $KMnO_4$ from MnO_2.

OR

6 (*b*) **I.** Account for the following: **2+2+1**

(*i*) Transition metals form alloys.

(*ii*) Ce^{4+} is a strong oxidising agent.

II. Write one similarity and one difference between chemistry of Lanthanoids and Actinoids.

III. Complete the following ionic equation:

$Cr_2O_7^{2-} + 2OH^- \longrightarrow$

Ans

6 (*a*) **I.** (*i*) It is because Mn^{2+} ($3d^5$) is more stable than Cr^{2+} ($3d^2$).

(*ii*) Sc^{3+} does not have unpaired electron where as Ti^{3+} has one unpaired electron, undergoes *d-d*-transition by absorbing light from visible region and radiate complementary colour.

(*iii*) 7*s*, 6*d* and 5*f* orbital electrons have nearly equal energy, therefore, more electrons take part in bor formation.

II. $2MnO_2 + 4KOH + O_2 \longrightarrow 2K_2MnO_4 + 2H_2O$

$MnO_4^{2-} \xrightarrow{\text{electrolysis}} MnO_4^- + e^-$

OR

6 (*b*) **I.** (*i*) Transition metals have almost equal size, can replace each other in metallic bonds to form alloys.

(*ii*) Ce^{4+} can gain one electron to form Ce^{3+} and $E^\circ_{Ce^{4+}/Ce^{3+}}$ is positive.

II. Both show contraction in atomic and ionic size.

Both have *f*-orbitals.

Difference: Lanthanoids show +3 oxidation state mostly along with +2 and +4, Actinoids show +3 to +7 oxidation states.

III. $\underset{\text{(Orange)}}{Cr_2O_7^{2-}} + 2OH^- \longrightarrow \underset{\text{(Yellow)}}{2CrO_4^{2-}} + H_2O$

CBSE 2024

1 Which of the following does ***not*** show variable oxidation states ?

CBSE-2024

(A) Fe

(B) Cu

(C) Mn

(D) Sc

2. Complete the following ionic equations :

(a) $2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow$

(b) $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow$

Ans.

(a)	$2\,MnO_4^- + 5\,SO_3^{2-} + 6\,H^+ \longrightarrow 2\,Mn^{2+} + 5\,SO_4^{2-} + 3\,H_2O$	1
(b)	$Cr_2O_7^{2-} + 14\,H^+ + 6\,Fe^{2+} \longrightarrow 2\,Cr^{3+} + 6\,Fe^{3+} + 7\,H_2O$	1

3. (a) Why do transition metals and their compounds act as good catalysts ? *1*

(b) What is the cause of contraction in the atomic size of lanthanoids ? *1*

(c) Define lanthanoid contraction. How does it affect the atomic radii of the third transition series and the second transition series ? *2*

OR

(c) In aqueous media, which is a stronger reducing agent — Cr^{2+} or Fe^{2+} and why ? *2*

Ans.

(a)Due to their ability to show multiple oxidation states and to form complexes / provide large surface area.	1
(b)Due topoor shielding effect of *4f* orbital .	1
(c) The overall decrease in atomic and ionic radii from La to Lu is known as lanthanoid contraction. Atomic radii of second and third transition series are very similar.	1,1
OR	
(c) Cr^{2+} is stronger reducing agent than Fe^{2+} Reason: $d^4 \rightarrow d^3$ occurs in case of Cr^{2+} to Cr^{3+} But $d^6 \rightarrow d^5$ occurs in case of Fe^{2+} to Fe^{3+} In a medium (like water) d^3 is more stable as compared to d^5	1,1

4 Transition metals are known to make interstitial compounds. Formation of interstitial compounds makes the transition metal

(*a*) more hard (*b*) more soft

(*c*) more ductile (*d*) more metallic

5. Attempt any **five** of the following: **1×5**

(*a*) Ce(III) is easily oxidised to Ce(IV). Comment.

(*b*) $E°(Mn^{2+}/Mn)$ is –1.18 V. Why is this value highly negative in comparison to neighbouring *d*-block elements?

(*c*) Which element of 3*d* series has lowest enthalpy of atomisation and why?

(*d*) What happens when sodium chromate is acidified?

(*e*) Zn, Cd and Hg are soft metals. Why?

(*f*) Why is permanganate titration not carried out in the presence of HCl?

(*g*) The lower oxides of transition metals are basic whereas the highest are amphoteric/acidic. Give reason.

Ans. (*a*) It is because Ce(IV), $[Xe]_{54}\ 4f^0 5d^0 6s^0$ has stable electronic configuration.

(*b*) It is due to stability of $Mn^{2+}(3d^5)$, half filled *d*-orbitals as compared to neighbouring *d*-block elements.

(*c*) Zinc, it is due to weak metallic bonds, which is due to completely filled *d*-orbitals.

(*d*) Sodium dichromate is formed which is orange in colour.

$$\underset{\text{Sodium chromate}}{2Na_2CrO_4} + H_2SO_4 \longrightarrow \underset{\text{Sodium dichromate}}{Na_2Cr_2O_7} + Na_2SO_4 + H_2O$$

(*e*) It is because these metals have weak metallic bonds due to absence of unpaired electrons and completely filled *d*-orbitals.

(*f*) It is because HCl gets oxidised by $KMnO_4$ to form H_2O and Cl_2.

(*g*) The lower oxides of transition metals are ionic, dissolve in water partially to form bases whereas higher oxides are covalent, hydrolyse to form acids e.g. MnO dissolves in water forming $Mn(OH)_2$ whereas Mn_2O_7 gives $HMnO_4$ (Permanganic acid) on hydrolysis. Some oxides are amphoteric in higher oxidation states due to partial ionic character.

CBSE 2025

1. **The magnetic moment is associated with its spin angular momentum and orbital angular momentum. Spin only magnetic moment value of Cr^{3+} ion (Atomic no. : Cr = 24) is:**

CBSE-2025

(A) 2.87 B.M.

(B) 3.87 B.M.

(C) 3.47 B.M.

(D) 3.57 B.M.

Ans 1:- **Calculation.** The magnetic moment (μ) is calculated using the formula:

$$\mu = \sqrt{n(n+2)}\,\text{B.M.}$$

Where n is the number of unpaired electrons. For Cr^{3+} (3 unpaired electrons), we get:

$$\mu = \sqrt{3(3+2)} = \sqrt{15} \approx 3.87\,\text{B.M.}$$

2. **Acidified $KMnO_4$ oxidizes sulphite to:**

(A) SO_3^{2-}

(B) SO_4^{2-}

(C) $SO_2(g)$

(D) $S_2O_8^{2-}$

3. **Complete and balance the following chemical equations:**

(a)

$$2MnO_4^-(aq) + 10I^-(aq) + 16H^+(aq) \rightarrow$$

(b)

$$Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \rightarrow$$

4. **The elements of 3d transition series are given as: Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn Answer the following:**

(a) Copper has an exceptionally positive $E^\circ_{M^{2+}/M}$ value, why?

(b) Which element is a strong reducing agent in +2 oxidation state and why?

(c) Zn^{2+} salts are colourless. Why?

5. The element having $[Ar]3d^{10}4s^1$ electronic configuration is

(A) Cu (B) Zn

(C) Cr (D) Mn

6. When $FeCr_2O_4$ is fused with Na_2CO_3 in the presence of air it gives a yellow solution of compound (A). Compound (A) on acidification gives compound (B). Compound (B) on reaction with KCl forms an orange coloured (C). An acidified solution of compound (C) oxidises Na_2SO_3 to (D). Identify (A), (B), (C) and (D). 2

7. (a) Of the d^4 species, Cr^{2+} is strongly reducing while Mn^{3+} is strongly oxidising. Why ? 3×1

(b) Write two consequences of lanthanoid contraction.

(c) Which element of 3d series has lowest enthalpy of atomisation and why ? Zn