CHAPTER

# 8

# 'd' AND 'f' BLOCK ELEMENTS

## Syllabus

- *General introduction, electronic configuration, occurrence and characteristics of transition metals, general trends in properties of the first row transition metals – metallic character, ionization enthalpy, oxidation states, ionic radii, colour, catalytic property, magnetic properties, interstitial compounds, alloy formation, preparation and properties of $K_2Cr_2O_7$ and $KMnO_4$.*
- *Lanthanoids : Electronic configuration, oxidation states, chemical reactivity and lanthanoid contraction and its consequences.*
- *Actinoids : Electronic configuration, oxidation states and comparison with lanthanoids.*

### Trend Analysis

| List of Concepts | 2018 | 2019 | | 2020 | |
|---|---|---|---|---|---|
| | D/OD | D | OD | D | OD |
| **Identification of compounds/elements/ ions** | | **1Q<br>(2 marks)** | **1Q<br>(2 marks)** | | **1Q<br>(3 marks)** |
| **Complete the equations** | **1Q<br>(2 marks)** | | | | **1Q<br>(2 marks)** |
| **Give reasons** | **1Q<br>(3 marks)** | **1Q<br>(3 marks)** | **1Q<br>(3 marks)** | **1Q<br>(5 marks)** | **1Q<br>(1 mark)** |
| **Properties of d-block elements** | | | | **1Q<br>(1 mark)** | |
| **Lanthanoids and actinoids** | **1Q<br>(2 marks)** | **2Q<br>(3 marks)** | **2Q<br>(3 marks)** | | |

## TOPIC-1
## d-Block Elements, their Properties and Compounds

## Revision Notes

- ***d*-block elements :** The elements in which last electron enters in the *d* - sub-shell i.e. penultimate shell and lies in the middle of the periodic table belonging to groups 3-12.
- **Transition elements :** The elements of *d*-block are known as transition elements as they possess properties that are transitional between the *s*-block and *p*-block elements. Transition elements are defined as elements which have incompletely filled *d*-orbitals in their ground states or in its most common oxidation state. Transition elements have four series :

  **(i) First transition series :** These elements have incomplete 3*d*-orbitals and they are from Sc (21) to Zn (30).

**(ii) Second transition series :** These elements have incomplete 4*d*-orbitals and they are from Y (39) to Cd (48).

**(iii) Third transition series :** These elements have incomplete 5*d*-orbitals and they are La (57) and then from Hf (72) to Hg (80).

**(iv) Fourth transition series :** This series is yet incomplete and these elements have incomplete 6*d*-orbitals. Known elements of this series are–actinium (89) and then from Rf (104) and other elements.

3. **General electronic configuration of transition elements :** Valence shell electronic configuration is $(n-1)d^{1-10}, ns^{1-2}$, where *n* is the outermost shell.

**Electronic configuration of *d*-block elements**

| Series | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 | Group 8 | Group 9 | Group 10 | Group 11 | Group 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3*d* series | Sc (21)<br>$4s^2 3d^1$ | Ti (22)<br>$4s^2 3d^2$ | V (23)<br>$4s^2 3d^3$ | Cr (24)<br>$4s^1 3d^5$ | Mn (25)<br>$4s^2 3d^5$ | Fe (26)<br>$4s^2 3d^6$ | Co (27)<br>$4s^2 3d^7$ | Ni (28)<br>$4s^2 3d^8$ | Cu (29)<br>$4s^1 3d^{10}$ | Zn (30)<br>$4s^2 3d^{10}$ |
| 4*d* series | Y (39)<br>$5s^2 4d^1$ | Zr (40)<br>$5s^2 4d^2$ | Nb (41)<br>$5s^1 4d^4$ | Mo (42)<br>$5s^1 4d^5$ | Tc (43)<br>$5s^2 4d^5$ | Ru (44)<br>$5s^1 4d^7$ | Rh (45)<br>$5s^1 4d^8$ | Pd (46)<br>$5s^0 4d^{10}$ | Ag (47)<br>$5s^1 4d^{10}$ | Cd (48)<br>$5s^2 4d^{10}$ |
| 5*d* series | La (57)<br>$6s^2 5d' 4f^0$ | Hf (72)<br>$6s^2 5d^2 4f^{14}$ | Ta (73)<br>$6s^2 5d^3 4f^{14}$ | W (74)<br>$6s^2 5d^4 4f^{14}$ | Re (75)<br>$6s^2 5d^5 4f^{14}$ | Os (76)<br>$6s^2 5d^6 4f^{14}$ | Ir (77)<br>$6s^2 5d^7 4f^{14}$ | Pt (78)<br>$6s^1 5d^9 4f^{14}$ | Au (79)<br>$6s^1 5d^{10} 4f^{14}$ | Hg (80)<br>$6s^2 5d^{10} 4f^{14}$ |
| 6*d* series | Ac (89)<br>$7s^2 5f^0 6d^1$ | Rf (104)<br>$7s^2 5f^{14} 6d^2$ | Db (105)<br>$7s^2 5df^{14} 6d^3$ | Sg (106)<br>$7s^2 5f^{14} 6d^4$ | Bh (107)<br>$7s^2 5f^{14} 6d^5$ | Hs (108)<br>$7s^2 5f^{14} 6d^6$ | Mf (109)<br>$7s^2 5f^{14} 6d^7$ | Ds (110)<br>$7s^2 5f^{14} 6d^8$ | Rg (111)<br>$7s^1 5f^{14} 6d^{10}$ | uub (112)<br>$7s^2 5f^{14} 6d^{10}$ |

➢ **General characteristics of Transition Elements :**

**Physical Properties :**

**(i)** All are metals.

**(ii)** All are malleable and ductile except mercury(liquid).

**(iii)** High thermal and electrical conductivity.

**(iv)** Metallic lustre and sonorous.

**(v)** **Atomic radii :** Smaller than those of *s*-block elements, larger than those of *p*-block elements in a period. In a transition series, as the atomic number increases, the atomic radii first decreases till the middle, becomes constant and then increases towards end of the period.

It usually increase down the group. The size of 4*d* elements is almost of the same size as of the 5*d* series elements. The filling of 4*d* before 5*d* orbitals results in regular decrease in atomic radii which is called as **lanthanoid contraction**.

**(vi)** **Ionic radii :** The ionic radii decrease, with increase in oxidation state.

**(vii)** **Density :** From left to right in a period, density increases.

**(viii)** **Ionisation enthalpy :** Along the series from left to right, there is an increase in ionisation enthalpy. Irregular trend in the I$^{st}$ ionisation enthalpy of 3*d* metals is due to irregularity in electronic configuration of 4*s* and 3*d* orbitals. In a group, IE decreases from 3*d* to 4*d*-series but increases from 4*d* to 5*d* series due to lanthanoid contraction.

**(ix)** **Metallic bonding :** In metallic bonding, regular lattice of positive ions are held together by a cloud of free electrons, which can move freely through the lattice. Transition metal atoms are held together by strong metallic bonds.

**(x)** **Enthalpy of atomisation :** Enthalpy of atomisation is the heat required to convert 1 mole of crystal lattice into free atoms. Transition elements have high enthalpy of atomisation. It first increases, becomes maximum in the middle of the series and then decreases regularly.

**(xi)** **Variable oxidation state :** Since the energies of *ns* and (*n*–1) *d* electrons are almost equal, therefore the electrons of both these orbitals take part in the reactions, due to which transition elements show variable oxidation states. Transition metal ions show variable oxidation states except the first and last member of the series.

**(xii)** **Electrode potential :** The electrode potential develops on a metal electrode when it is in equilibrium with a solution of its ions, leaving electrons from the electrode. Transition metals have lower value of reduction potential. Variation in E° value is irregular due to the regular variation in ionisation enthalpies ($I.E_1 + I.E_2$), sublimation and hydration enthalpies.

**(xiii)** **Catalytic properties :** Many of the transition metals and their compounds, particularly oxides act as catalysts for a number of chemical reactions. Iron, cobalt, nickel, platinum, chromium, manganese and their compounds are commonly used catalysts.

All transitional metals show multiple oxidation states and have large surface area so, all metals work as a catalyst.

**(xiv)** **Magnetic properties :** On the basis of the behaviour of substances in magnetic field, they are of two types : (i) Diamagnetic, (ii) Paramagnetic.

Diamagnetic substances have paired electrons only. *e.g.,* Zn has no (zero) paired electrons.

In paramagnetic substances, it is necessary to have at least one unpaired electron. Paramagnetism increases with the increase in number of unpaired electrons.

Paramagnetism may be measured by magnetic moment.

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

where $n$ = number of unpaired electrons in atom or ion and B.M. = Bohr magneton (unit of magnetic moment). Diamagnetic and paramagnetic substances are repelled and attracted in the magnetic field respectively (Magnetic properties of transition elements).

**(xv) Melting and boiling points :** Except zinc, cadmium and mercury, all other transition elements have high melting and boiling points. This is due to strong metallic bonds and presence of partially filled *d*-orbitals in them.

**(xvi) Complex formation :** They have tendency to form complex ions due to high charge on the transition metal ions and the availability of *d*-orbitals for accommodating electrons donated by the ligand atoms.

**(xvii) Formation of coloured compounds :** Transition metals form coloured ions due to the presence of unpaired *d*-electrons. As a result, light is absorbed in the visible region to cause excitation of unpaired *d*-electrons ($d-d$ transition) and colour observed corresponds to the complementary colour of the light absorbed. $Cu^{+}$, $Zn^{2+}$ and $Cd^{2+}$ are colourless due to the absence of unpaired *d*-electron ($d^{10}$).

**(xviii) Formation of alloys :** Alloy formation is due to almost similar size of the metal ions, their high ionic charges and the availability of *d*-orbitals for bond formation. Therefore, these metals can mutually substitute their position in their crystal lattice to form alloys. eg. steel, brass.

**(xix) Formation of interstitial compounds :** Interstitial compounds are known for transition metals as small-sized atoms of H, B, C, N, etc. can easily occupy positions in the voids present in the crystal lattices of transition metals. Characteristics of interstitial compounds :

- High melting points
- Hard
- Chemically inert
- Retain metallic conductivity
- Non-stoichiometric

➢ **Oxides of Transition metals :** They form oxides of the general composition MO, $M_2O_3$, $MO_2$, $M_2O_5$ and $MO_6$. Oxides in the lower oxidation states are generally basic while those in the higher oxidation states are amphoteric or acidic. For example,

| +2 | +3 | +8, +3 | +4 | +7 |
|---|---|---|---|---|
| MnO | $Mn_2O_3$ | $Mn_3O_4$ | $MnO_2$ | $Mn_2O_7$ |
| Basic | Amphoteric | Amphoteric | Amphoteric | Acidic |

➢ **Potassium Dichromate ($K_2Cr_2O_7$)**

**Preparation :** It is prepared from chromate ore in the following steps :

**(i)** Chromite ore is fused with sodium carbonate in the presence of air to give sodium chromate.

$$4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 2Fe_2O_3 + \underset{\text{Sodium chromate}}{8Na_2CrO_4} + 8CO_2$$

**(ii)** $Na_2CrO_4$ is filtered and acidified with conc. $H_2SO_4$ to give $Na_2Cr_2O_7$.

$$2Na_2CrO_4 + 2H^+ \rightarrow Na_2Cr_2O_7 + 2Na^+ + H_2O.$$

**(iii)** Sodium dichromate solution is treated with KCl to give $K_2Cr_2O_7$.

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

**Properties :**

**(a)** It is an orange, crystalline solid.

**(b) With alkali :**

$$Cr_2O_7^{2-} + 2OH^- \rightarrow \underset{\substack{\text{Chromate ion}\\ \text{(Yellow)}}}{2CrO_4^{2-}} + H_2O$$

**(c) With acid :**

$$2CrO_4^{2-} + 2H^+ \rightarrow \underset{\substack{\text{Dichromate ion}\\ \text{(orange red)}}}{Cr_2O_7^{2-}} + H_2O$$

In acidic solutions, oxidising action is

$$\mathbf{Cr_2O_7^{2-}} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

**(d)** It is a powerful oxidising agent. For example,

(i) It oxidises ferrous to ferric.

$$\begin{array}{c} Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \\ [Fe^{2+} \rightarrow Fe^{3+} + e^-] \times 6 \\ \hline Cr_2O_7^{2-} + 6Fe^{2+}\ 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O \\ \hline \end{array}$$

**(ii)** It oxidises stannous to stannic.

$$\begin{array}{c} Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \\ [Sn^{2+} \rightarrow Sn^{4+} + 2e^-] \times 3 \\ \hline Cr_2O_7^{2-} + 3Sn^{2+}\ 14H^+ \rightarrow 2Cr^{3+} + 7H_2O + 3Sn^{4+} \\ \hline \end{array}$$

**(iii)** It oxidises sulphur dioxide to sulphate.

$$\begin{aligned} Cr_2O_7^{2-} + 14H^+ + 6e^- &\rightarrow 2Cr^{3+} + 7H_2O \\ [SO_2 + 2H_2O &\rightarrow SO_4^{2-} + 4H^+ + 2e^-] \times 3 \\ \hline Cr_2O_7^{2-} + 3SO_2 + 2H^+ &\rightarrow 2Cr^{3+} + 3SO_4^{2-} + H_2O \end{aligned}$$

**(iv)** It oxidises hydrogen sulphide to sulphur.

$$\begin{aligned} Cr_2O_7^{2-} + 14H^+ + 6e^- &\rightarrow 2Cr^{3+} + 7H_2O \\ [H_2S &\rightarrow 2H^+ + S + 2e^-] \times 3 \\ \hline Cr_2O_7^{2-} + 3H_2S + 8H^+ &\rightarrow 2Cr^{3+} + 3S + 7H_2O \end{aligned}$$

**(v)** It oxidises iodides to iodine.

$$\begin{aligned} Cr_2O_7^{2-} + 14H^+ + 6e^- &\rightarrow 2Cr^{3+} + 7H_2O \\ [2I^- &\rightarrow I_2 + 2e^-] \times 3 \\ \hline Cr_2O_7^{2-} + 6I^- + 14H^+ &\rightarrow 2Cr^{3+} + 3I_2 + 7H_2O \end{aligned}$$

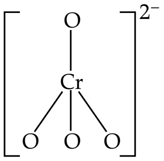
**Uses :**

**(i)** In leather industry for chrome tanning.

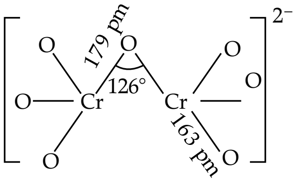
**(ii)** Preparation of azo compounds.

**(iii)** As a primary standard in volumetric analysis for the estimation of reducing agent.

**Structure :**



**Chromate ion**



**Dichromate ion**

- **Potassium permanganate ($KMnO_4$)**

**Preparation :**

**(i)** It is prepared from pyrolusite ore with KOH in the presence of oxidising agent like $KNO_3$. The dark green potassium manganate undergoes electrolytic oxidation to produce potassium permanganate.

$$2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4 + 2H_2O$$

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

**(ii)** Commercially, it is prepared by alkaline oxidative fusion of $MnO_2$ followed by electrolytic oxidation of manganate (VI).

$$MnO_2 + 2e^- \xrightarrow[\text{Oxidised with air/}KNO_3]{\text{Fused with KOH}} \underset{\text{Manganate ion}}{MnO_4^{2-}}$$

$$MnO_4^{2-} \xrightarrow[\text{in alkaline solution}]{\text{Electrolytic oxidation}} \underset{\text{Permanganate ion}}{MnO_4^- + 1e^-}$$

**(iii)** In laboratory, by oxidation of manganese (II) ion salt by peroxodisulphate.

$$2Mn^{2+} + \underset{\text{Peroxodisulphate}}{5S_2O_8^{2-}} + 8H_2O \rightarrow 2MnO_4^- + 10SO_4^{2-} + 16H^+$$

**Properties :**

**(i)** Dark purple crystalline solid

**(ii)** Sparingly soluble in water

**(iii)**Decomposes on heating at 513 K

$$2KMnO_4 \rightarrow K_2MnO_4 + MnO_2 + O_2$$

**(iv)**Acts as a powerful oxidising agent in acidic, alkaline and neutral medium. For example :

**1. In acidic medium oxidises :**

**(i)** Iodide to iodine

$$\begin{aligned} [MnO_4^- + 8H^+ + 5e^- &\rightarrow Mn^{2+} + 4H_2O] \times 2 \\ [2I^- &\rightarrow I_2 + 2e^-] \times 5 \\ \hline 2MnO_4^- + 10I^- + 16H^+ &\rightarrow 2Mn^{2+} + 5I_2 + 8H_2O \end{aligned}$$

**(ii)** Ferrous to ferric

$$\begin{aligned} MnO_4^- + 8H^+ + 5e^- &\rightarrow Mn^{2+} + 4H_2O \\ [Fe^{2+} &\rightarrow Fe^{3+} + e^-] \times 5 \\ \hline MnO_4^- + 5Fe^{2+} + 8H^+ &\rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O \end{aligned}$$

**(iii)** Oxalate to carbon dioxide :

$$\begin{array}{rl}
[MnO_4^- + 8H + 5e^- & \rightarrow Mn^{2+} + 4H_2O] \times 2 \\
[C_2O_4^{2-} & \rightarrow 2CO_2 + 2e^-] \times 5 \\
\hline
2MnO_4^- + 5C_2O_4^{2-} + 16H^+ & \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O \\
\hline
\end{array}$$

**(iv)** Hydrogen sulphide to sulphur

$$\begin{array}{rl}
[MnO_4^- + 8H^+ + 5e^- & \rightarrow Mn^{2+} + 4H_2O\,] \times 2 \\
[S^{2-} & \rightarrow S + 2e^-] \times 5 \\
\hline
2MnO_4^- + 5S^{2-} + 16H^+ & \rightarrow 2Mn^{2+} + 5S + 8H_2O \\
\hline
\end{array}$$

**(v)** Sulphite to sulphate

$$\begin{array}{rl}
[MnO_4^- + 8H^+ + 5e^- & \rightarrow Mn^{2+} + 4H_2O] \times 2 \\
[SO_3^{2-} + H_2O & \rightarrow SO_4^{2-} + 2H^+ + 2e^-] \times 5 \\
\hline
5SO_3^{2-} + 2MnO_4^- + 6H^+ & \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O \\
\hline
\end{array}$$

**(vi)** Nitrite to nitrate

$$\begin{array}{rl}
[MnO_4^- + 8H^+ + 5e^- & \rightarrow Mn^{2+} + 4H_2O] \times 2 \\
[NO_2^- + H_2O & \rightarrow NO_3^- + 2H^+ + 2e^-] \times 5 \\
\hline
2MnO_4^- + 5NO_2^- + 6H^+ & \rightarrow 2Mn^{2+} + 5NO_3^- + 3H_2O \\
\hline
\end{array}$$

2. **In neutral alkaline medium :**

**(i)** Iodide to iodate

$$\begin{array}{rl}
[MnO_4^- + 2H_2O + 3e^- & \rightarrow MnO_2 + 4OH^-] \times 2 \\
I^- + 6OH^- & \rightarrow IO_3^- + 3H_2O + 6e^- \\
\hline
2MnO_4^- + I^- + H_2O & \rightarrow IO_3^- + 2MnO_2 + 2OH^- \\
\hline
\end{array}$$

**(ii)** Manganous to manganese dioxide

$$2MnO_4^- + 3Mn^{2+} + 2H_2O \rightarrow 5MnO_2 + 4H^+$$

**(iii)** Thiosulphate to sulphate

$$8MnO_4^- + 3\,S_2O_3^{2-} + H_2O \rightarrow 8MnO_2 + 6SO_4^{2-} + 2OH^-$$

**Uses :**

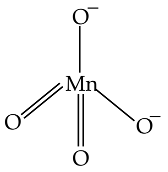
**(i)** Bleaching of wool, silk, cotton and other textile fibres etc.

**(ii)** Decolourisation of oils.

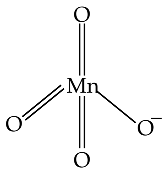
**(iii)** In analytical chemistry (titration).

**(iv)** In organic synthesis.

**Structure :**



Tetrahedral manganate ion (Green)



Tetrahedral permanganate ion (Purple)

## Mnemonics

### 3-d series

- **Concept:** First Row Transition Elements-3-d series
- **Mnemonic: Sc**ary **Ti**ny **Vi**cious **Cr**eatures **Min**gle (with) **Fe**llow **Co**w **Ni**lgai **Cou**gar **Z**ebra.
- Interpretation: Scandium**(Sc)**, Titanium**(Ti)**, Vanadium**(V)**, Chromium**(Cr)**, Manganese**(Mn)**, Iron**(Fe)**, Cobalt**(Co)**, Nickel**(Ni)**, Copper**(Cu)**, Zinc**(Zn)**

### 4-d series

- **Concept:** Second Row Transition Elements-4-d series
- **Mnemonics: Y**esterday **Z**ora **N**a**b**bed a **Mo**nkey **TR**i**c**king her **Rh**eumatic **P**a**d**osan **Ag**nes **Cad**illac.
- **Interpretation:** Y, Zr, Nb > Mo, Tc, Ru, Rh, Pd, Ag, Cd

**5-d series**

- **Concept:** Third Row Transition Elements-5-d series
- **Mnemonic:** Late Harry Took Walk, Reached Office In Pajamas After an Hour.
- **Interpretation:** La......, Hf, Ta, W, Re, OS, Ir, Pt, Au, Hg

## Know the Terms

- **Oxidation state :** The measure of the electronic state of an atom in a particular compound and is equal to the number of electron; it has in the valence shell, more than or less than the number of electrons in free atom.
- **Ferromagnetic substances :** Substances which are attracted very strongly by the applied magnetic field. *e.g.,* Fe, Co, Ni etc.

## How is it done on the GREENBOARD?

**Q. (i) For $M^{2+}/M$ and $M^{3+}/M^{2+}$ systems, E° values for some metals are as follows :**

**$Cr^{2+}/Cr = -0.9$ V $Cr^{3+}/Cr^{2+} = -0.4$ V**

**$Mn^{2+}/Mn = -1.2$ V $Mn^{3+}/Mn^{2+} = +1.5$ V**

**$Fe^{2+}/Fe = -0.4$ V $Fe^{3+}/Fe^{2+} = +0.8$ V**

**Use this data to comment upon**

**(a) the stability of $Fe^{3+}$ in acid solution as compared to that of $Cr^{3+}$ and $Mn^{3+}$.**

**(b) the ease with which iron can be oxidised as compared to the similar process for either Cr or Mn metals.**

**(ii) What can be inferred from the magnetic moment of the complex $K_4[Mn(CN)_6]$ ? (Magnetic moment : 2.2 BM)**

**Solution:**

**STEP - I :** (i) (a) $Cr^{3+}/Cr^{2+}$ has a negative reduction potential. Hence, $Cr^{3+}$ cannot be reduced to $Cr^{2+}$. $Cr^{3+}$ is most stable. $Mn^{3+}/Mn^{2+}$ have large positive E° values. Hence, $Mn^{3+}$ can be easily reduced to $Mn^{2+}$. Thus $Mn^{3+}$ is least stable. $Fe^{3+}/Fe^{2+}$ couple has a positive E° value but is small. Thus, the stability of $Fe^{3+}$ is more than $Mn^{3+}$ but less stable than $Cr^{3+}$. **[1]**

**(b)** If we compare the reduction potential values, $Mn^{2+}/Mn$ has the most negative value i.e., its oxidation potential value is most positive. Thus, it is most easily oxidised. Therefore, the decreasing order for their ease of oxidation is Mn > Cr > Fe. **[1]**

**STEP - I :** (ii) (ii) $K_4[Mn(CN)_6]$

Mn is in +2 oxidation state. Magnetic moment 2.2 indicates that it has one unpaired electron and hence forms inner orbital or low spin complex. In presence of $CN^-$ which is a strong ligand, hybridisation involved is $d^2sp^3$ (octahedral complex). **[1]**

## Objective Type Questions

**(1 mark each)**

**[A] MULTIPLE CHOICE QUESTIONS :**

**Q. 1. Electronic configuration of a transition element X in +3 oxidation state is $[Ar]3d^5$. What is its atomic number?**

**(a) 25** **(b) 26**

**(c) 27** **(d) 24**

**A [NCERT Exemp. Q. 1, Page 105]**

**Ans. Correct option : (b)**

*Explanation :* It is formed by the loss of 3 electrons, the configuration of element $X$ is $[Ar]\ 3d^6 4s^2$.

Therefore, Atomic number = 26.

**Q. 2. The electronic configuration of Cu(II) is $3d^9$ whereas that of Cu(I) is $3d^{10}$. Which of the following is correct?**

**(a) Cu(II) is more stable**

**(b) Cu(II) is less stable**

**(c) Cu(I) and Cu(II) are equally stable**

**(d) Stability of Cu(I) and Cu(II) depends on nature of copper salts**

U **[NCERT Exemp. Q. 2, Page 105]**

**Ans. Correct option : (a)**

*Explanation :* Cu(II) is more stable due to nuclear charge of Cu.

**Q. 3. When $KMnO_4$ solution is added to oxalic acid solution, the decolourisation is slow in the beginning but becomes instantaneous after some time because**

**(a) $CO_2$ is formed as the product.**

**(b) Reaction is exothermic.**

**(c) $MnO_4^-$ catalyses the reaction.**

**(d) $Mn^{2+}$ acts as auto-catalyst.**

A&E **[NCERT Exemp. Q. 9, Page 107]**

**Ans. Correct option : (d)**

*Explanation :* When $KMnO_4$ solution is added to oxalic acid solution, the decolourisation is slow in the beginning but becomes instantaneous after sometime because $Mn^{2+}$ acts as an auto-catalyst.

Reduction half-reaction :

$$[MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O] \times 2$$

Oxidation half-reaction :

$$[C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-] \times 5$$

Overall equation :

$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

End point of this reaction : Colourless to light pink.

**Q. 4. When acidified $K_2Cr_2O_7$ solution is added to Sn salts then $Sn^{2+}$ changes to**

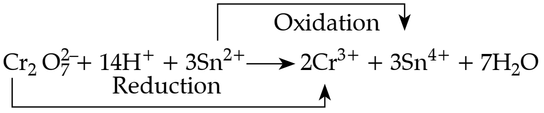
**(a) Sn** **(b) $Sn^{3+}$**

**(c) $Sn^{4+}$** **(d) $Sn^+$**

A **[NCERT Exemp. Q. 18, Page 108]**

**Ans. Correct option : (c)**

*Explanation :* When acidified $K_2Cr_2O_7$ solution is added to $Sn^{2+}$ salt, $Sn^{2+}$ changes to $Sn^{4+}$. The reaction is given here :



$$Cr_2O_7^{2-} + 14H^+ + 3Sn^{2+} \longrightarrow 2Cr^{3+} + 3Sn^{4+} + 7H_2O$$

**Q.5. The oxidation state of Ni in $[Ni(CO)_4]$ is**

**(a) 0** **(b) 2**

**(c) 3** **(d) 4**

U **[CBSE Delhi Set 1, 2020]**

**Ans. Correct option : (a) 0**

*Explanation :*

Let oxidation state of Ni = $x$

$x + 0 = 0$ (CO is neutral ligand)

$x = 0$

AI **Q.6. Which of the following is the reason for Zinc not exhibiting variable oxidation state ?**

**(a) inert pair effect**

**(b) completely filled 3d subshell**

**(c) completely filled 4s subshell**

**(d) common ion effect**

**Ans. Correct option :** (b) **[CBSE SQP 2021]**

*Explanation :* Zinc does not exhibit a variable oxidation state as it has completely filled 3d subshell.

Zn — $[Ar]\ 3d^{10}\ 4s^2$ Atomic number 30

**Q. 7. Which of the following is a diamagnetic ion ? (Atomic numbers of Sc, V, Mn and Cu are 21, 23, 25 and 29 respectively)**

**(a) $V^{2+}$** **(b) $Sc^{3+}$**

**(c) $Cu^{2+}$** **(d) $Mn^{3+}$**

**Anw. Correct option :** (b)

*Explanation :* $Sc^{3+}$ is a diamagnetic ion. Atomic number is 21.

$[Ar]3d^0$ is $Sc^{3+}$ electronic configuration. Since its d subshell is empty it is diamagnetic as it has noble gas configuration.

**Q.8. Which set of ions exhibit specific colours? (Atomic number of Sc = 21, Ti = 22, V=23, Mn = 25, Fe = 26, Ni = 28 Cu = 29 and Zn =30)**

**(a) $Sc^{3+}$, $Ti^{4+}$, $Mn^{3+}$** **(b) $Sc^{3+}$, $Zn^{2+}$, $Ni^{2+}$**

**(c) $V^{3+}$, $V^{2+}$, $Fe^{3+}$** **(d) $Ti^{3+}$, $Ti^{4+}$, $Ni^{2+}$**

A&E **[CBSE SQP 2021]**

**Ans. Correct option :** (c)

*Explanation :* $V^{3+}$, $V^{2+}$, $Fe^{3+}$ ions exhibit specific colours.

Atomic number of V = 23,

Electronic configuration of V - $[Ar]3d^3\ 4s^2$

Electronic configuration of $V^{2+}$ - $[Ar]3d^3$

Electronic configuration of $V^{3+}$ - $[Ar]\ 3d^2$

Atomic number of Fe = 26

Electronic configuration of Fe - $[Ar]3d^6\ 4s^2$

Electronic configuration of $Fe^{3+}$ - $[Ar]3d^5$

Since these ions have partially filled d- subshells, they exhibit colour. Most transition-metal ions have a partially filled d subshell.

As for other ions,

Atomic number of Sc = 21

Electronic configuration of Sc - $[Ar]3d^1\ 4s^2$

Electronic configuration of $Sc^{3+}$ - $[Ar]3d^0$

Since d subshell is empty, it shows no colour.

Atomic number of Ti = 22

Electronic configuration of Ti- $[Ar]3d^2\ 4s^2$

Electronic configuration of $Ti^{4+}$ - $[Ar]3d^0$

Since d subshell is empty, it shows no colour.

Atomic number of Mn =25

Electronic configuration of Mn- $[Ar]3d^5\ 4s^2$

Electronic configuration of $Mn^{2+}$ $[Ar]3d^4$

Since d subshell is partially filled, it shows colour.
Atomic number of Ni = 28
Electronic configuration of Ni- $[Ar]3d^8\ 4s^2$
Electronic configuration of $Ni^{4+}$ $[Ar]3d^8$
Since d subshell is partially filled, it shows colour.
Atomic number of Zn =30
Electronic configuration of Zn- $[Ar]3d^{10}\ 4s^2$
Electronic configuration of $Zn^{2+}$- $[Ar]3d^{10}$
Since d subshell is full, it shows no colour.

**[B] ASSERTION & REASON TYPE QUESTIONS :**

**(a) Both assertion and reason are correct statements, and reason is the correct explanation of the assertion.**
**(b) Both assertion and reason are correct statements, but reason is not the correct explanation of the assertion.**
**(c) Assertion is correct, but reason is wrong statement.**
**(d) Assertion is wrong, but reason is correct statement.**

**Q. 1. Assertion (A) : $Cu^{2+}$ iodide is not known.**
**Reason (R) : $Cu^{2+}$ oxidises $I^-$ to iodine.**
**R [NCERT Exemplar]**

**Ans. Correct option : (a)**

*Explanation :* $Cu^{2+}$ oxidises iodide to iodine hence cupric iodide is converted to cuprous iodide.

**Q. 2. Assertion (A) : The highest oxidation state of osmium is +8.**
**Reason (R) : Osmium is a 5d-block element.** R

**Ans. Correct option : (b)**

*Explanation :* The highest oxidation state of osmium (Os) is +8. It is due to its ability to expand octet by using its all 8 electrons.

**Q. 3. Assertion (A) : Separation of Zr and Hf is difficult.**
**Reason (R) : Because Zr and Hf lie in the same group of the periodic table. R [NCERT Exemplar]**

**Ans. Correct option : (b)**

*Explanation :* Separation of Zr and Hf is difficult as both have same size.

**Q. 4. Assertion (A) : Cu cannot liberate hydrogen from acids.**
**Reason (R) : Because it has positive electrode potential. R [NCERT Exemplar]**

**Ans. Correct option : (a)**

*Explanation :* Copper (Cu) does not liberate hydrogen from acids due to the presence of positive electrode potential.

**Q. 5. Assertion (A) : Transition metals have low melting points.**
**Reason (R) : The involvement of greater number of $(n-1)d$ and $ns$ electrons in the interatomic metallic bonding. U [CBSE OD Set-1, 2020]**

**Ans. Correct option : (d)**

*Explanation :* Transition metals have high melting points because of the involvement of greater number of $(n-1)d$ and $ns$ electrons in the interatomic metallic bonding.

**Q. 6. Assertion (A) : Transition metals have high melting point.**
**Reason (R) : Transition metals have completely filled $d$-orbitals. U [CBSE OD Set-2, 2020]**

**Ans. Correct option : (c)**

*Explanation :* Transition metals have high melting points because of the involvement of greater number of $(n-1)d$ and ns electrons in the interatomic metallic bonding.

**[C] VERY SHORT ANSWER TYPE QUESTIONS :**

**Q. 1. Write the formula of an oxo-anion of Manganese (Mn) in which it shows the oxidation state equal to its group number. A [CBSE Delhi Set-1, 3 2017]**

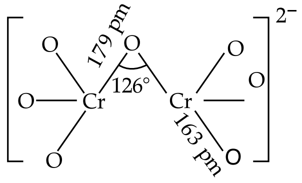
**Ans.** $MnO_4^-/KMnO_4$
**[CBSE Marking Scheme 2017]**

**Q. 2. Write the formula of an oxo-anion of Chromium (Cr) in which it shows the oxidation state equal to its group number. A [CBSE Delhi Set-2 2017]**

**Ans.** $Cr_2O_7^{2-}/CrO_4^{2-}/K_2Cr_2O_7/K_2CrO_4$
**[CBSE Marking Scheme 2017]**

**Q. 3. Give the structure of dichromate ion.** R

**Ans.**



## Short Answer Type Questions-I

**(2 marks each)**

**Q. 1. What are the transition elements ? Write two characteristics of the transition elements.**
**R [CBSE Delhi 2015]**

**Ans.** These atoms whose $d$-orbitals are incomplete in ground state or in one of the most common oxidation state are called transition elements or $d$-block elements. The valence shell electronic configuration of transition elements is $(n\text{-}1)d^{1\text{-}10}ns^{1\text{-}2}$. **[1]**

**Two characteristics of transition elements :**
**(i)** Transition metals show variable oxidation states. **[1]**
**(ii)** All transition metals act as catalyst.

**Commonly Made Error**

- Students tend to write irrelevant information on characteristics thus losing time.

**Answering Tip**

- Use the precise definition and mention the main characteristics.

AI **Q. 2. What is meant by 'disproportionation' ? Give an example of a disproportionation reaction in aqueous solution.** R

**OR**

**Suggest reasons for the following features of transition metal chemistry :**

**(i) The transition metals and their compounds are usually paramagnetic.**

**(ii) The transition metals exhibit variable oxidation states.** A&E **[CBSE Comptt. Delhi 2015]**

**Ans.** Disproportionation is the reaction in which an element undergoes self-oxidation and self-reduction simultaneously. For example – **[1]**

$2Cu^+ (aq) \rightarrow Cu^{2+} (aq) + Cu(s)$ **[1]**

(Or any other correct equation)

**OR**

**(i)** Due to presence of unpaired electrons in *d*-orbitals. **[1]**

**(ii)** Due to incomplete filling of d-orbitals. Due to very small energy difference in between $(n - 1)\,d$ and $n\,s$-orbitals. **[1]**

**[CBSE Marking Scheme 2015]**

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

**(a)** $Fe^{2+} + MnO_4^- + H^+ \rightarrow$

**(b)** $MnO_4^- + H_2O + I^- \rightarrow$ A **[CBSE Delhi/OD 2018]**

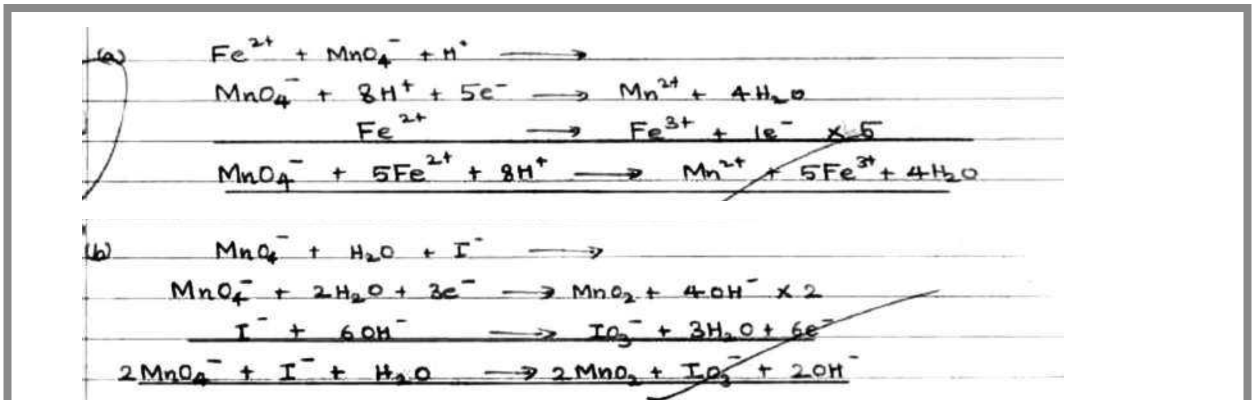
**Ans. (a)** $5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$ **[1]**

**(b)** $2MnO_4^- + H_2O + I^- \rightarrow 2MnO_2 + 2OH^- + IO_3^-$ **[1]**

*(Half mark to be deducted in each equation for not balancing)*

**[CBSE Marking Scheme 2018]**

**Detailed Answer :**



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

$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$

$Fe^{2+} \longrightarrow Fe^{3+} + 1e^- \times 5$

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

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

$MnO_4^- + 2H_2O + 3e^- \longrightarrow MnO_2 + 4OH^- \times 2$

$I^- + 6OH^- \longrightarrow IO_3^- + 3H_2O + 6e^-$

$2MnO_4^- + I^- + H_2O \longrightarrow 2MnO_2 + IO_3^- + 2OH^-$

**[Topper's Answer 2018] [2]**

**Commonly Made Error**

- Many students write unbalanced equations. Some students fail to write the correct products.

**Answering Tip**

- Write all the reactants and products clearly. Balance the equation.

**Q. 4. In the following ions :**

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

**(Atomic no : Mn = 25, V = 23, Cr = 24, Ti = 22)**

**(a) Which ion is most stable in an aqueous solution?**

**(b) Which ion is the strongest oxidizing agent?**

**(c) Which ion is colourless?**

**(d) Which ion has the highest number of unpaired electrons?**

U **[CBSE Foreign Set-1, 2, 3 2017]**

**Ans. (a)** $Cr^{3+}$ **[½]** **(b)** $Mn^{3+}$ **[½]**

**(c)** $Ti^{4+}$ **[½]** **(d)** $Mn^{3+}$ **[½]**

**[CBSE Marking Scheme 2017]**

**Q. 5. Explain the following observations :**

**(i) Copper atom has completely filled *d* orbitals ($3d^{10}$) in its ground state, yet it is regarded as a transition element.**

**(ii) $Cr^{2+}$ is a stronger reducing agent than $Fe^{2+}$ in aqueous solution.**

A&E **[CBSE Comptt. OD Set-1 2017]**

**Ans. (i)** Because it has incompletely filled *d* orbitals in one of its oxidation state ($Cu^{2+}$). **[1]**

**(ii)** $Cr^{2+}(d^4)$ changes to $Cr^{3+}(d^3)$ while $Fe^{2+}(d^6)$ changes to $Fe^{3+}$ $(d^5)$. In aqueous medium $d^3$ is more stable than $d^5$. **[1]**

**[CBSE Marking Scheme 2017]**

**Q. 6. Name the following :**

**(i) A transition metal which does not exhibit variation in oxidation state in its compounds.**

**(ii) A compound where the transition metal is in the +7 oxidation state.**

**(iii) A member of the lanthanoid series which is well known to exhibit +4 oxidation state.**

**(iv) Ore used in the preparation of Potassium dichromate.** R **[CBSE SQP 2016]**

**Ans. (i)** Scandium (Sc). **[½]**

**(ii)** $KMnO_4$ or any other suitable example. **[½]**

**(iii)** Cerium (Ce) or any other example. **[½]**

**(iv)** Chromite ore. **[½]**

**Q. 7. Explain the following observation**

**(i) $Zn^{2+}$ salt are colourless.**

**(ii) Copper has exceptionally positive $E^o_{M^{2+}/M}$ value.**

**A&E [CBSE Comptt. OD Set-3 2017]**

**Ans. (i)** Due to absence of unpaired electrons. **[1]**

**(ii)** Due to high $\Delta_a H°$ and low $\Delta_{hyd} H°$. **[1]**

**[CBSE Marking Scheme 2017]**

**Detailed Answer :**

**(i)** Zinc has no unpaired electrons in its d orbital and has a stable fully filled *d* orbital state. Thus, due to absence of unpaired electrons, $Zn^{2+}$ salts are colourless. **[1]**

**(ii)** As copper has high energy of atomisation $\Delta_a H°$ and low hydration energy $\Delta_{hyd} H°$, due to which E° value is positive. **[1]**

**Commonly Made Error**

- Students lose time in giving unnecessary explanation.

**Answering Tip**

- Write the cause and consequence of the condition.

**Q. 8. Give reasons :**

**(i) Zn is not regarded as a transition element.**

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

**A&E [CBSE Comptt. Delhi 2016]**

**Ans. (i)** In both, Zn and $Zn^{2+}$ ions absence of incompletely filled *d*-orbital therefore, Zn is not regarded as a transition element. **[1]**

**(ii)** $Cr^{2+}$ has $d^4$ configuration while $Cr^{3+}$ has more stable $d^3$ ($t_{2g}^3$) configuration. Thus, Cr has a tendency to acquire $Cr^{3+}$ due to greater stability of +3 oxidation state. Therefore, $Cr^{2+}$ acts as a strong a reducing agent. **[CBSE Marking Scheme, 2016] [1]**

**Q. 9. Explain the following observation :**

**(i) Silver atom has completely filled *d*-orbitals ($4d^{10}$) in its ground state, yet it is regarded as a transition element.**

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

**A&E [CBSE Comptt. OD Set-2 2017]**

**Ans. (i)** Silver can exhibit +2 oxidation state, wherein it will have incompletely filled *d*-orbital. **[1]**

**(ii)** Much higher third ionisation energy of Mn where the required change is from $d^5$ to $d^4$. **[1]**

**[CBSE Marking Scheme 2017]**

**Q. 10. When chromite ore $FeCr_2O_4$ is fused with NaOH in presence of air, a yellow coloured compound (A) is obtained which on acidification with dilute sulphuric acid gives a compound (B). Compound (B) on reaction with KCl forms a orange coloured crystalline compound (C).**

**(i) Write the formulae of the compounds (A), (B) and (C).**

**(ii) Write one use of compound (C).** **U**

**Ans. (i)** $4FeCr_2O_4 + 16NaOH + 7O_2 \rightarrow 8Na_2CrO_4$ [A] $+ 2Fe_2O_3 + 8H_2O$

$2Na_2CrO_4$ [A] $+ H_2SO_4 \rightarrow Na_2Cr_2O_7$ [B] $+ Na_2SO_4 + H_2O$

$Na_2Cr_2O_7$ [B] $+ 2KCl \rightarrow K_2Cr_2O_7$ [C] $+ 2NaCl$

A : $Na_2CrO_4$ B : $Na_2Cr_2O_7$

C : $K_2Cr_2O_7$ **[1]**

**(ii) Use of $K_2Cr_2O_7$ (C) :** It is used as a strong oxidizing agent in industries. **[1]**

**Q. 11. Complete the following chemical equations :**

**(i) $KMnO_4^- + 3S_2O_3^{2-} + H_2O \rightarrow$ ?**

**(ii) $Cr_2O_7^{2-} + 3Sn^{2+} + 14H^+ \rightarrow$ ?**

**R [CBSE Delhi 2016]**

**Ans. (i)** $MnO_4^- + 3S_2O_3^{2-} + H_2O \rightarrow 2OH^- + 6SO_4^{2-} + MnO_2$ **[1]**

**(ii)** $Cr_2O_7^{2-} + 3Sn^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 7H_2O + 3Sn^{4+}$ **[1]**

**Q. 12. Describe the preparation of potassium permanganate. How does the acidified permanganate solution react with oxalic acid ? Write the ionic equations for the reactions.**

**Ans.** Potassium permanganate is prepared by fusion of $MnO_2$ with an alkali metal hydroxide and an oxidising agent like $KNO_3$. This produces the dark green $K_2MnO_4$ which disproportionate in a neutral or acidic solution to give permanganate.

$2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4 + 2H_2O$

$3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4 + MnO_2 + 2H_2O$ **[1]**

Oxalate ion or oxalic acid is oxidised at 333 K :

$5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$ **[1]**

**[CBSE Marking Scheme 2015]**

**Commonly Made Error**

- Many students write unbalanced equations. Some students do not write the correct products.

**Answering Tip**

- Write the balanced chemical equations involved in the preparation.

**Q. 13. Describe the oxidising action of potassium dichromate and write the ionic equations for its reaction with (i) an iodide (ii) $H_2S$.**

**R [CBSE Comptt. OD 2015]**

**Ans. (i)** $Cr_2O_7^{2-} + 6I^- + 14H^+ \rightarrow 2Cr^{3+} + 3I_2 + 7H_2O$ **[1]**

**(ii)** $Cr_2O_7^{2-} + 3H_2S + 8H^+ \rightarrow 2Cr^{3+} + 3S + 7H_2O$ **[1]**

**[CBSE Marking Scheme 2015]**

**Q. 14. When $MnO_2$ is fused with KOH in presence of $KNO_3$ as an oxidizing agent, it gives a dark green compound (A). Compound (A) disproportionate 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).** **A&E** **[CBSE Delhi Set-I, 2019]**

**Ans.** A = $K_2MnO_4$ / $MnO_4^{2-}$, B = $KMnO_4$ / $MnO_4^-$, C = $KIO_3$/ $IO_3^-$, D = $I_2$

**[CBSE Marking Scheme, 2019] [½ × 4]**

**Detailed Answer :**

**(A)** $K_2MnO_4$ (green)

$$2MnO_2 + 4KOH + O_2 \rightarrow \underset{\text{Compound A}}{2K_2MnO_4} + 2H_2O$$

**(B)** $KMnO_4$ (purple)

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

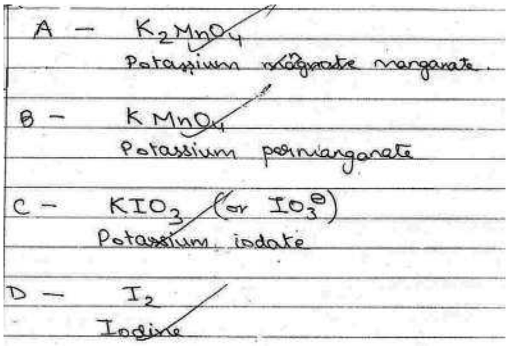
**(C)** $IO_3^-$

$$2MnO_4^- + H_2O + I^- \rightarrow 2MnO_2 + 2OH^- + \underset{\text{Compound C}}{IO_3^-}$$

**(D)** $I_2$

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

**[2]**



A — $K_2MnO_4$
Potassium manganate.
B — $KMnO_4$
Potassium permanganate
C — $KIO_3$ (or $IO_3^\ominus$)
Potassium iodate
D — $I_2$
Iodine

**[Topper's Answer 2019] [2]**

**Q. 15. 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 compound (C). An acidified solution of compound (C) oxidises $Na_2SO_3$ to (D). Identify (A), (B), (C) and (D).**

**Ans.** A = $Na_2CrO_4$, B=$Na_2Cr_2O_7$, C= $K_2Cr_2O_7$, D= $Na_2SO_4$

**[CBSE Marking Scheme, 2019] [½ × 4 = 2]**

**Detailed Answer :**

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

**[A]**

$$2Na_2CrO_4 + 2H^+ \longrightarrow Na_2Cr_2O_7 + 2Na^+ + H_2O$$

**[B]**

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

**[C]**

$$K_2Cr_2O_7 + 3Na_2SO_3 + 4H_2SO_4 \longrightarrow 3Na_2SO_4 + K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O$$

[D]

[A] $Na_2CrO_4$ : Sodium chromate, [B] $Na_2Cr_2O_7$ : Sodium dichromate,

[C] $K_2Cr_2O_7$ : Potassium dichromate, [D] $Na_2SO_4$ : Sodium sulphate. **[2]**

**Q. 16. Write the balanced chemical equations involved in the preparation of $KMnO_4$ from pyrolusite ore ($MnO_2$).**

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

$$3K_2MnO_4 + 2CO_2 \longrightarrow 2KMnO_4 + \underset{\text{(ppt)}}{MnO_2} + 2K_2CO_3$$

**Q. 17. Write the balanced ionic equations showing the oxidising action of acidified dichromate ($Cr_2O_7^{2-}$). solution with(i) Iron (II) ion and (ii) tin (II) ion.** **A**

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

**(ii)** $Cr_2O_7^{2-} + 3Sn^{2+} + 14H^+ \longrightarrow 2Cr^{3+} + 3Sn^{4+} + 7H_2O$

## Short Answer Type Questions-II

**(3 marks each)**

**Q. 1. The magnetic moment of few transition metal ions are given below :**

| **Metal ion** | **Magnetic moment (BM)** |
|---|---|
| **$Sc^{3+}$** | **0.00** |
| **$Cr^{2+}$** | **4.90** |
| **$Ni^{2+}$** | **2.84** |
| **$Ti^{3+}$** | **1.73** |

**(Atomic no. Sc = 21, Ti = 22, Cr = 24, Ni = 28)**

**Which of the given metal ions :**

**(i) has the maximum number of unpaired electrons?**
**(ii) force colourless aqueous solution?**
**(iii) exhibits the most stable +3 oxidation state?**

**Ans. (i)**$Cr^{2+}$ **[1]**

**(ii)** $Sc^{3+}$ **[1]**

**(iii)** $Sc^{3+}$ **[1]**

**Q. 2. Consider the standard electrode potential values ($M^{2+}$/M) of the elements of the first transition series.**

| Ti | V | Cr | Mn | Fe |
|---|---|---|---|---|
| –1.63 | –1.18 | –0.90 | –1.18 | –0.44 |
| Co | Ni | Cu | Zn | |
| –0.28 | –0.25 | +0.34 | –0.76 | |

**Explain :**

**(i) E° value for copper is positive.**

**(ii) E° value of Mn is more negative as expected from the trend.**

**(iii) $Cr^{3+}$ is a stronger reducing agent than $Fe^{2+}$.**

A **[CBSE SQP 2017]**

**Ans. (i)** The high energy to transform Cu(s) to $Cu^{2+}$(aq) is not balanced by its hydration enthalpy. **[1]**

**(ii)** $Mn^{2+}$ has $d^5$ configuration (stable half-filled configuration) **[1]**

**(ii)** $d^5$ to $d^3$ occurs in case of $Cr^{2+}$ to $Cr^{3+}$.(More stable $t^3 2g$) while it changes from $d^6$ to $d^5$ in case of $Fe^{2+}$ to $Fe^{3+}$. **[1]**

**[CBSE Marking Scheme 2017]**

**Q. 3. (i) Complete the following equations :**

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

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

**(ii) Based on the data, arrange $Fe^{2+}$, $Mn^{2+}$ and $Cr^{2+}$ in the increasing order of stability of +2 oxidation state.**

$E^{\circ}{Cr^{3+}/Cr^{2+}} = -0.4\ V$

$E^{\circ}{Mn^{3+}/Mn^{2+}} = +1.5\ V$

$E^{\circ}{Fe^{3+}/Fe^{2+}} = +0.8\ V$

R + U

**Ans. (i) (a)** $2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow 2Mn^{2+} + 3H_2O + 5SO_4^{2-}$ **[1]**

**(b)** $Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$ **[1]**

**(ii)** $Cr^{2+} < Fe^{2+} < Mn^{2+}$ **[1]**

**Q. 4. Write the preparation of following :**

**(i) $KMnO_4$ from $K_2MnO_4$**

**(ii) $Na_2CrO_4$ from $FeCr_2O_4$**

**(iii) $Cr_2O_7^{2-}$ from $CrO_4^{2-}$**

R **[CBSE Comptt. Delhi/OD 2018]**

**Ans. (i)** $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$ **[1]**

(or any other correct equation)

**(ii)** $4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$ **[1]**

**(iii)** $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ **[1]**

**[CBSE Marking Scheme 2018]**

**Q. 5. Account for the following :**

**(i) $CuCl_2$ is more stable than $Cu_2Cl_2$.**

**(ii) Atomic radii of 4*d* and 5*d* series elements are nearly same.**

**(iii) Hydrochloric acid is not used in permanganate titration.** A&E **[CBSE Foreign Set-1, 2 2017]**

**Ans. (i)** In $CuCl_2$, Cu is in +2 oxidation state which is more stable due to high hydration enthalpy as compared to $Cu_2Cl_2$ in which Cu is in +1 oxidation state. **[1]**

**(ii)** Due to lanthanoid contraction. **[1]**

**(ii)** Because HCl is oxidised to chlorine. **[1]**

**[CBSE Marking Scheme 2017]**

**Q. 6. (i) Give reasons for the following :**

**(a) Compounds of transition elements are generally coloured.**

**(b) MnO is basic while $Mn_2O_7$ is acidic.**

**(ii) Calculate the magnetic moment of a divalent ion in aqueous medium if its atomic number is 26.**

A&E + A **[CBSE Comptt. OD Set-1, 2, 3 2017]**

**Ans. (i) (a)** Due to *d-d* transition. **[1]**

**(b)** Due to higher oxidation state of $Mn_2O_7$ / Due to high polarizing power of Mn(VII). **[1]**

**(ii)** $\mu = \sqrt{4(4+2)} = 4.90$ B.M. **[1]**

**[CBSE Marking Scheme 2017]**

**Q. 7. Give reasons :**

**(i) Mn shows the highest oxidation state of +7 with oxygen but with fluorine it shows the highest oxidation state of +4.**

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

**(iii) Actinoids show irregularities in their electronic configurations.** A&E **[CBSE Delhi Set-1, 2016]**

**Ans. (i)** Mn can form $p\pi$ -$d\pi$ bond with oxygen by using 2*p* orbital of oxygen and 3*d*-orbital of Mn because of which it shows highest oxidation state of +7.

With fluorine, Mn cannot form $p\pi - d\pi$ bond thus shows the highest oxidation state of +4. **[1]**

**(ii)** Transition metal show variable oxidation state due to comparable energies of *ns* and (*n* – 1)*d* orbitals and partially filled *d* orbitals. So, both these orbitals take part in the reactions. **[1]**

**(iii)** Due to comparable energies of 5*f*, 6*d* and 7*s* orbitals and the relative stabilities of $f^0$, $f^7$ and $f^{14}$ occupancies of the 5*f* orbitals. **[1]**

**Commonly Made Error**

- Students donot read the question properly or write long explanations to the questions asked.

**Answering Tip**

- Be specific while writing reason. Avoid unnecessary explanations.

**Q. 8. (i) Account for the following :**

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

**(b) Transition metals form complex compounds.**

**(ii) Complete the following equation :**

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

A&E + R **[CBSE OD 2015]**

**Ans. (i) (a)** Because $Cu^+$ undergoes disproportionation as $2Cu^+ \rightarrow Cu + Cu^{2+}$.

Hydration enthalpy of $Cu^{2+}$ is higher than that of $Cu^+$ which compensates the $I.E._2$ of Cu involved in the formation of $Cu^{2+}$ ions. **[1]**

**(b)** Because of small size of metal, high ionic charge and availability of vacant *d*-orbital. **[1]**

**(ii)** $Cr_2O_7^{2-} + 8H^+ + 3NO_2^- \rightarrow 2Cr^{3+} + 3NO_3^- + 4H_2O$ (Balanced equation only) **[1]**

**[CBSE Marking Scheme 2015]**

**Q. 9. Give reasons :**

**(a) E° 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.**

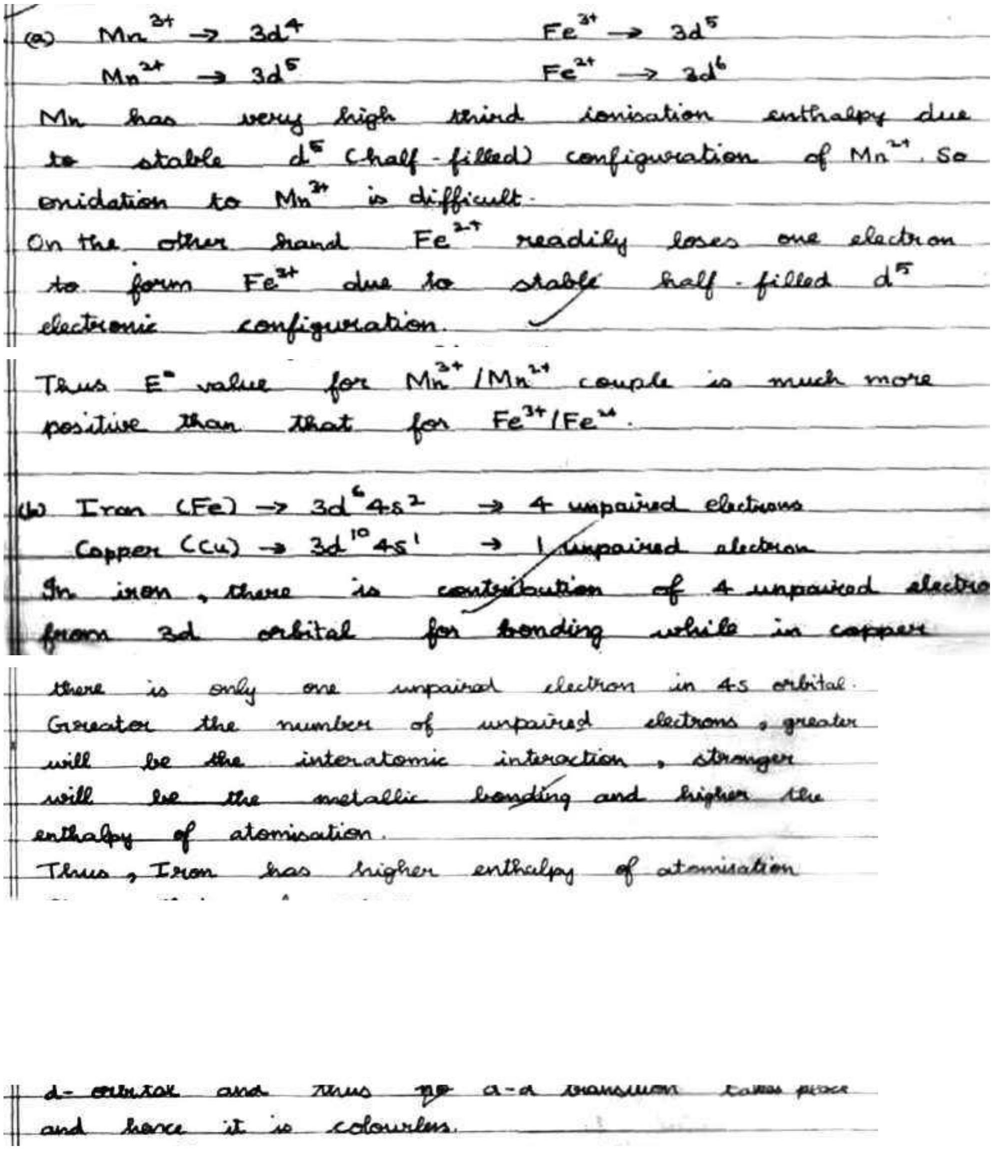
**(c) $Sc^{3+}$ is colourless in aqueous solution whereas $Ti^{3+}$ is coloured.** A&E **[CBSE Delhi/OD 2018]**

**Ans. (a)** Because $Mn^{2+}$ is more stable than $Mn^{3+}$ due to half-filled $d^5$ configuration whereas $Fe^{2+}$ becomes unstable after loosing an electron from half-filled orbital. **[1]**

**(b)** Due to presence of higher number of unpaired electrons in iron, they have stronger metallic bonding. Hence, the enthalpy of atomization is more of iron than that of copper. **[1]**

**(c)** $Sc^{3+}$ is colourless as it does not contain unpaired electrons to undergo *d-d* transition while $Ti^{3+}$ is coloured as it contains unpaired electrons to undergo d-d transition by absorbing light from visible region and radiate complementary colour. **[1]**

**[CBSE Marking Scheme 2018]**



(a) $Mn^{3+} \rightarrow 3d^4$ $Fe^{3+} \rightarrow 3d^5$

$Mn^{2+} \rightarrow 3d^5$ $Fe^{2+} \rightarrow 3d^6$

Mn has very high third ionisation enthalpy due to stable $d^5$ (half-filled) configuration of $Mn^{2+}$. So oxidation to $Mn^{3+}$ is difficult.

On the other hand $Fe^{2+}$ readily loses one electron to form $Fe^{3+}$ due to stable half-filled $d^5$ electronic configuration.

Thus E° value for $Mn^{3+}/Mn^{2+}$ couple is much more positive than that for $Fe^{3+}/Fe^{2+}$.

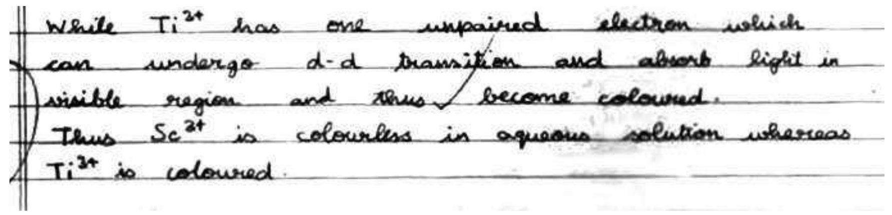
(b) Iron (Fe) → $3d^6 4s^2$ → 4 unpaired electrons

Copper (Cu) → $3d^{10} 4s^1$ → 1 unpaired electron

In iron, there is contribution of 4 unpaired electro from 3d orbital for bonding while in copper there is only one unpaired electron in 4s orbital. Greater the number of unpaired electrons, greater will be the interatomic interaction, stronger will be the metallic bonding and higher the enthalpy of atomisation.

Thus, Iron has higher enthalpy of atomisation

d- orbital and thus no d-d transition takes place and hence it is colourless.



While $Ti^{3+}$ has one unpaired electron which can undergo d-d transition and absorb light in visible region and thus become coloured.
Thus $Sc^{3+}$ is colourless in aqueous solution whereas $Ti^{3+}$ is coloured.

**[Topper's Answer 2018]**

**Q. 10. A mixed oxide of iron and chromium is fused with sodium carbonate in free access of air to form a yellow coloured compound (A). On acidification the compound (A) forms an orange coloured compound (B), which is a strong oxidizing agent. Identify compound (A) and (B). Write chemical reactions involved.**

**A [CBSE Comptt. OD Set-1, 2, 3 2017]**

**Ans. A :** $Na_2CrO_4$ **B :** $Na_2Cr_2O_7$ ½+½

$4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$ **1**

$2Na_2CrO_4 + 2H^+ \rightarrow Na_2Cr_2O_7 + 2Na^+ + H_2O$ **1**

**[CBSE Marking Scheme 2017]**

**Commonly Made Error**

- Most of the students write either incorrect or incomplete equations. In many cases, the equations are unbalanced.

**Answering Tip**

- Write complete and balanced chemical equations.

**Q. 11. Give reasons for the following :** **[3]**

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

**(b) E° value for ($Zn^{2+}$ /Zn) is negative while that of ($Cu^{2+}$ /Cu) is positive.**

**(c) Higher oxidation state of Mn with fluorine is +4 whereas with oxygen is +7.**

**R & U [CBSE OD Set-2 2019]**

**Ans. (i)** Because of comparable energies of ($n$ – 1)d and ns orbitals / Incomplete filling of $d$-orbital.

**(ii)** Because of stable $3d^{10}$ configuration of $Zn^{2+}$ whereas due to low hydration enthalpy and high enthalpy of atomization of $Cu^{2+}$.

**(iii)** Due to the ability of oxygen to form multiple bonds with metal.

**[CBSE Marking Scheme, 2019] [1 × 3 = 3]**

**Detailed Answer :**

**(a)** Because of availability of partially filled orbitals and comparable energies of ns and (n – 1)d orbitals.

**(b)** E° value for ($Zn^{2+}$/Zn) is negative due to stable completely filled $d^{10}$ configuration in $Zn^{2+}$. The positive value of ($Cu^{2+}$/Cu) accounts for its ability to liberate $H_2$ from acids due to its high enthalpy of atomization and low hydration energy.

**(c)** Mn can form multiple bonds with oxygen by using 2p orbital of oxygen and 3d orbital of Mn because of which it shows highest oxidation state of +7 with fluorine, Mn cannot form multiple bonds thus shows an oxidation state of +4. **[3]**

**Q. 12. Give reasons for the following :**

**(i) Transition elements act as catalysts**

**(ii) It is difficult to obtain oxidation state greater than two for Copper.**

**(iii) $Cr_2O_7^{2-}$ is a strong oxidising agent in acidic medium whereas $WO_3$ and $MoO_3$ are not.**

**Ans. (i)** Due to large surface area and ability to show variable oxidation states. **[1]**

**(ii)** Due to high value of third ionisation enthalpy. **[1]**

**(iii)** Mo(VI) and W(VI) are more stable than Cr(VI). **[1]**

**Q. 13. Observed and calculated values for the standard electrode potentials of elements from Ti to Zn in the first reactivity series are depicted in figure (1) :**

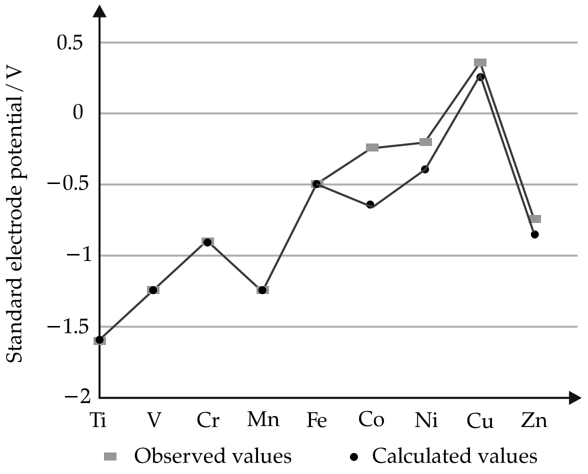


FIGURE 1

**Explain the following observations :**

**(i) The general trend towards less negative E° values across the series**

**(ii) The unique behaviour of Copper**

**(iii) More negative E° values of Mn and Zn**

**A&E [CBSE SQP 2021]**

**Ans. (i)** The general trend towards less negative $E°$ V values across the series is related to the general increase in the sum of the first and second ionisation enthalpies. **[1]**

**(ii)** The high energy to transform Cu(s) to $Cu^{2+}$ (aq) is not balanced by its hydration enthalpy. **[1]**

**(iii)** The stability of the half-filled *d* sub-shell in $Mn^{2+}$ and the completely filled $d^{10}$ configuration in $Zn^{2+}$ are related to their more negative $E°$ V values **[1]**

**Q.14. Following ions are given :**
**$Cr^{2+}$, $Cu^{2+}$, $Cu^{+}$, $Fe^{2+}$, $Fe^{3+}$, $Mn^{3+}$**
**Identify the ion which is**
**(i) a strong reducing agent.**
**(ii) unstable in aqueous solution.**
**(iii) a strong oxidising agent.**
**Give suitable reason in each.**

A **[CBSE OD Set-1 2020]**

**Ans. (i)** $Cr^{2+}$, because its configuration changes from $d^4$ to $d^3$ and having a half-filled $t_{2g}$ level.

**(ii)** $Cu^+$ in an aqueous medium energy is required to remove one electron from $Cu^+$ to $Cu^{2+}$, high hydration energy of $Cu^{2+}$ compensates for it. Therefore $Cu^+$ ion in an aqueous solution is unstable.

$$2Cu^+ \longrightarrow Cu^{2+}(aq) + Cu(s)$$

**(iii)** $Mn^{3+}$, because its configuration changes from $Mn^{3+}$ to $Mn^{2+}$ results in the half filled $d^5$ configuration, which has extra stability.

## Long Answer Type Questions

**(5 marks each)**

AI **Q. 1. (i) Following are the transition metal ions of 3d series :**
**$Ti^{4+}$, $V^{2+}$, $Mn^{3+}$, $Cr^{3+}$**
**(Atomic number : Ti = 22, V = 23, Mn = 25, Cr = 24)**
**Answer the following :**
**(a) Which ion is most stable in an aqueous solution and why?**
**(b) Which ion is a strong oxidizing agent and why?**
**(c) Which ion is colourless and why?**
**(ii) Complete the following equations :**
**(a) $2MnO_4^- + 16H^+ + 5S^{2-} \rightarrow$**
**(b) $KMnO_4 \xrightarrow{heat}$**

A + R **[CBSE OD Set-1, 2, 3 2017]**

**Ans. (i) (a)** $Cr^{3+}$, half filled $t^3_{2g}$ [½+½]

**(b)** $Mn^{3+}$, due to stable $d^5$ configuration in $Mn^{2+}$ [½+½]

**(c)** $Ti^{4+}$, No unpaired electrons [½+½]

**(ii) (a)** $2MnO_4^- + 16H^+ + 5S^{2-} \rightarrow 5S + 2Mn^{2+} + 8H_2O$ **[1]**

**(b)** $2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + O_2$ **[1]**

**[CBSE Marking Scheme 2017]**

**Commonly Made Error**

- Students do not read and understand the question in a hurry.
- Many students write unbalanced equations. Some students do not write the correct products.

**Answering Tips**

- Read the question carefully. Do not forget to answer the sub-parts.
- Write complete and balanced chemical equation.

**Q. 2. (i) Complete the following equations :**
**(a) $Cr_2O_7^{2-} + 2OH^- \rightarrow$**
**(b) $MnO_4^- + 4H^+ + 3e^- \rightarrow$**
**(ii) Account for the following :**
**(a) Zn is not considered as a transition element.**
**(b) Transition metals form a large number of complexes.**
**(c) The E° value for the $Mn^{3+}/Mn^{2+}$ couple is much more positive than that for $Cr^{3+}/Cr^{2+}$ couple.**

R + A&E **[CBSE OD 2014]**

**Ans. (i) (a)** $Cr_2O_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$ **[1]**

**(b)** $MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$ **[1]**

**(ii) (a)** Because $Zn/Zn^{2+}$ has fully filled *d*-orbitals. **[1]**

**(b)** This is due to smaller ionic sizes, higher ionic charge and availability of *d*-orbitals. **[1]**

**(c)** Because $Mn^{2+}$ is more stable ($3d^5$) than $Mn^{3+}$($3d^4$), while $Cr^{+3}$ is more stable due to $t_2g^3/d^3$ configuration. **[1]**

**[CBSE Marking Scheme 2014]**

**Q. 3. When chromite ore is fused with sodium carbonate in free excess of air and the product is dissolved in water, a yellow solution of compound (A) is obtained. On acidifying the yellow solution with sulphuric acid, compound (B) is crystallized out. When compound (B) is treated with KCl, orange crystals of compound (C) crystallize out. Identify (A), (B) and (C) and write the reactions involved.**

A **[CBSE Comptt. OD Set-1, 2, 3 2017]**

**Ans. A :** $Na_2CrO_4$ **B :** $Na_2Cr_2O_7$ **C :** $K_2Cr_2O_7$ [½+½+1]

$4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$ **[1]**

$2Na_2CrO_4 + 2H^+ \rightarrow Na_2Cr_2O_7 + 2Na^+ + H_2O$ **[1]**

$Na_2Cr_2O_7 + 2KCl \rightarrow K_2Cr_2O_7 + 2NaCl$ **[1]**

**[CBSE Marking Scheme 2017]**

**Commonly Made Error**

- Most of the students write either incorrect or incomplete equations. In many cases, the equations are unbalanced.

**Answering Tip**

- Write complete and balanced chemical equations.

# TOPIC-2
## f-Block Elements : Lanthanoids and Actinoids

## Revision Notes

- ***f*-block elements :** The elements in which filling of electrons takes place in (*n*–2) *f*-subshell which belongs to anti-penultimate (third to the outermost) energy shell. This block consists of two series of elements known as **Lanthanoids and Actinoids**. These elements are also known as inner transition elements. The general electronic configuration of the *f* - block elements is

  $$(n-2)f^{1-14}\,(n-1)d^{0-1}\,ns^2$$

  For Lanthanoids, *n* is 6 while its value is 7 for Actinoids. There are many exceptions in the electronic configuration.
- **Lanthanoids :** The series involving the filling of 4*f*-orbitals following lanthanum La (Z = 57) is called the lanthanoid series. There are 14 elements in this series starting with Ce (Z = 58) to Lu (Z = 71).
  - **Electronic configuration :** [Xe] $4f^{1-14}\,5d^{0-1}\,6s^2$
  - **Physical properties :**

    **(i)** Highly dense metals, soft, malleable and ductile.

    **(ii)** High melting point.

    **(iii)** Forms alloys easily with other metals.

    **(iv)** **Magnetic Properties :** Among lanthanoids, $La^{3+}$ and $Lu^{3+}$ which have $4f^0$ or $4f^{14}$ electronic configurations are diamagnetic and all other trivalent lanthanoid ions are paramagnetic due to presence of unpaired electrons.

    **(v)** **Atomic and ionic sizes :** With increasing atomic number, the atomic and ionic radii decreases from one element to the other but the decrease is very small.

    A steady decrease in the size of lanthanoids with increase in atomic number is known as **lanthanoid contraction.**

    **Consequences of Lanthanoid contraction :**

    (a) It leads to similar physical and chemical properties among lanthanoids.

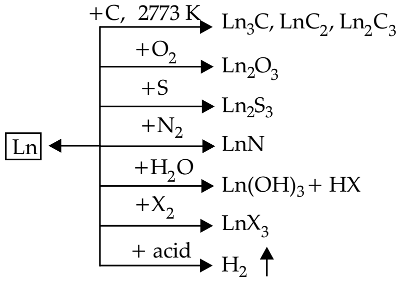
    (b) Zr and Hf have same properties, due to similar atomic radii.

    (c) Chemical separation of lanthanoids become difficult.

    **(vi)** **Oxidation state :** They mainly give +3 oxidation state. Some elements show +2 and +4 oxidation states.

    **(vii)** **Colour :** Some of the trivalent ions are coloured. This happens due to the absorption in visible region of the spectrum resulting in *f-f* transitions.

    **Chemical properties :** All lanthanoids are highly electropositive metals and have almost similar chemical reactivity.



**Uses :**

**(i)** Misch metal is the alloy of cerium (about 55%) and various other Lanthanoid elements (40-43%). It also contains iron upto 5% and traces of sulphur, carbon, silicon calcium and aluminium. It is a pyrophoric material, hence it is used in lighter flints.

**(ii)** Lanthanoid oxides are used for polishing glass.

**(iii)** Cerium salts are used in dyeing cotton and also as catalysts.

**(iv)** Lanthanoid compounds are used as catalyst for hydrogenated dehydrogenation and petroleum cracking.

**(v)** Pyrophoric alloys are used for making tracer bullets and shells.

- **Actinoids :** The series involving the filling of 5*f* orbitals from actinium, Ac (Z = 89) upto lawrencium, Lr (Z = 103) comprises of actinoids.
  - **Electronic configuration :** [Rn] $5f^{1-14}\,6d^{0-1}\,7s^2$

- **Physical properties :**
  - **(i)** Highly dense metals and form alloys with other metals.
  - **(ii)** Silvery white metals.
  - **(iii)** Highly electropositive.
  - **(iv)** High melting point.
  - **(v)** **Ionic and atomic radii :** The atomic and ionic size decreases with an increase in atomic number due to actinoid contraction. The electrons are added to 5*f* shell resulting in an increase in the nuclear charge causing the shell to shrink inwards. This is known as actinoid contraction.
  - **(vi)** **Colour :** Many actinoid ions are coloured.
  - **(vii)** **Magnetic properties :** Many actinoid ions are paramagnetic.
  - **(viii)** **Oxidation State :** The common oxidation state exhibited is +3. They also exhibit oxidation state of +4, +5, +6 and +7.
  - **(ix)** Many elements are radioactive.
- **Chemical reactivity :** Less reactive towards acids.
- **Uses :**
  - (i) Thorium is used in the treatment of cancer and in incandescent gas mantles.
  - **(ii)** Uranium is used in the glass industry, in medicines and as nuclear fuel.
  - **(iii)** Plutonium is used in atomic reactors and in atomic bombs.

➢ **Difference between Lanthanoids and Actinoids :**

| S. No. | Lanthanoids | Actinoids |
|---|---|---|
| **(i)** | 4*f* orbital is progressively filled. | 5*f* orbital is progressively filled. |
| **(ii)** | +3 oxidation state is most common along with +2 and +4. | +3 oxidation state is most common, but exhibit higher oxidation state of +4, +5, +6, +7. |
| **(iii)** | Except promethium, all are non-radioactive. | All are radioactive. |
| **(iv)** | Less tendency of complex formation. | Strong tendency of complex formation. |
| **(v)** | Chemically less reactive than actinoids. | More reactive than lanthanoids. |

## Mnemonics

**Lanthanides**

- Concept Name: Lanthanides Series
- Mnemonic: **La**te **CE**O **Pr**omoted **N**a**d**ia **P**almer **Sm**art to **Eu**rope so she said **G**oo**d**bye to **T**o**b**y a **Day** before **Ho**arding **Er**oding **Tim**ber in **Y**ard of **Lu.**
- Interpretation: La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

**Actinides**

- Concept Name: Actinide Series
- Mnemonic : **Active Th**or **Pa**id **U**r **N**e**p**hew for **Pu**mpkins.
- **Am**y **C**a**m**e **B**ac**k** from **C**ali**f**ornia.
- **E**in**s**tein and **F**er**m**i **M**a**d**e **No**. of **L**aws.
- Interpretation: Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr

## Know the Terms

➢ **Transuranic elements :** All the elements beyond uranium are known as transuranic or man-made elements. These elements do not occur in nature because their half-life periods are so short.

## How is it done on the GREENBOARD?

**Q. (i) How would you account for the following :**

**(a) Actinoid contraction is greater than lanthanoid contraction.**

**(b) Transition metals form coloured compounds.**

**(ii) Complete the following equation :**

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

**Solution:**

**STEP - I :** (i) (a) Actinoid contraction is greater than lanthanoid contraction due to more effective shielding by intervening 5f-electrons.

**STEP - II :** (b) Transition elements generally forms coloured compounds on account of d-d transition. When the visible light falls on the compounds, they absorb certain radiations and reflect others. The colour observed corresponds to absorbed light.

**(ii)** $2MnO_4^- + 6H^+ + 5NO_2^- \longrightarrow 5NO_3^- + 2Mn^{2+} + 3H_2O$.

## Objective Type Questions

**(1 mark each)**

### [A] MULTIPLE CHOICE QUESTIONS :

**Q. 1. Which of the following statements is not correct?**

**(a) La is actually transition element.**

**(b) In Lanthanide series, Ionic radii decrease from $La^{3+}$ to $Lu^{3+}$.**

**(c) $La(OH)_3$ is less basic than $Lu(OH)_3$**

**(d) Ionic radii of Zr and Hf are almost similar due to Lanthanoid contraction.** U

**Ans. Correct option : (c)**

*Explanation :* $La(OH)_3$ is more basic than $Lu(OH)_3$. It is because of the fact that

Due to lanthanoid contraction the size of lanthanoid ion decreases regularly with increase in atomic size. Thus covalent character between lanthanoid ion and $OH^-$ increases from $La^{3+}$ to $Lu^{3+}$. Thus the basic character of hydroxides decreases from $La(OH)_3$ to $Lu(OH)_3$.

**Q. 2. Lanthanoid contraction is caused due to**

**(a) Atomic number**

**(b) Size of 4f orbitals**

**(c) Effective nuclear charge**

**(d) Poor shielding effect of 4f electrons** R

**Ans. Correct option : (d)**

*Explanation :* The lanthanoid contraction is due to poor shielding effect of 4f electrons.

**Q. 3. In which of the following elements, 5f orbitals are progressively filled?**

**(a) Alkaline earth metals**

**(b) Actinoids**

**(c) Lanthanoids**

**(d) Transition elements** R

**Ans. Correct option : (b)**

*Explanation :* Actinoids are 5f block elements so in actinoids, 5f orbitals are progressively filled.

### [B] ASSERTION & REASON TYPE QUESTIONS :

**In the following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.**

**(a) Assertion and reason both are correct statements and reason is the correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not the correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.**

**Q. 1. Assertion (A) : Chromium is an actinoid.**

**Reason (R) : In chromium, 3d orbitals are filled.** U

**Ans. Correct option : (d)**

*Explanation :* Chromium is a transition element and it belongs to 3d series because in chromium, 3d orbitals are filled.

**Q. 2. Assertion (A) : Chemistry of Actinoids is more complicated than Lanthanoids.**

**Reason (R) : Actinoid elements are radioactive in nature.** U

**Ans. Correct option : (a)**

*Explanation :* Chemistry of actinoids is more complicated than Lanthanoids because actinoids are radioactive elements having relatively short half-lives.

**Q. 3. Assertion (A) : Cerium (Ce) exhibits +4 oxidation state.**

**Reason (R) : $Ce^{4+}$ has $4f^4$ electronic configuration which is less stable.** U

**Ans. Correct option : (c)**

*Explanation :* Cerium exhibits +4 oxidation state because $Ce^{4+}$ has $4f^0$ electronic configuration which is most stable.

**[C] VERY SHORT ANSWER TYPE QUESTIONS :**

**Q. 1. Why Lanthanoids cannot be easily separated?** A

**Ans.** Due to lanthanoid contraction, the chnge in the atomic or ionic radii of these elements is very small. So, their chemical properties are similar. Hence, Lanthanoids cannot be easily separated

**Q.2. Why does Zr (Z=40) and Hf (Z=72) exhibit almost identical atomic radii?** A&E

**Ans.** Lanthanoid contraction is responsible for almost same atomic radii of 4d and 5d transition series elements.

**Q.3. Actinoid series members exhibit a large number of oxidation states compared to their corresponding lanthanoids. Why?** A&E

**Ans.** Due to comparable energies of 5f, 6d and 7s levels members of actinoid series exhibit a large number of oxidation states.

## Short Answer Type Questions-I

**(2 marks each)**

**Q. 1. Write one similarity and one difference between the chemistry of lanthanoids and actinoids ?**

U **[CBSE OD 2015]**

**Ans. Similarity : (i)** Both show contraction in size. **(ii)** Both show irregularity in their electronic configuration. **(iii)** Both are stable in +3 oxidation state. **[1]**

**Difference : (i)** Actinoids are mainly radioactive but lanthanoids are not. **(ii)** Actinoids show wide range of oxidation states but lanthanoids do not. **(iii)** Actinoid contraction is greater than lanthanoid contraction. **[1]**

**(Write any one of these or any other one similarity and one difference)**

**Commonly Made Error**

- Students lose time in description for 1 mark questions.

**Answering Tip**

- Students write irrelevant content. Be specific. Read question carefully and write only what is asked.

**Q. 2. Identify the following :**

**(i) Oxo anion of chromium which is stable in acidic medium.**

**(ii) The lanthanoid element that exhibits +4 oxidation state.**

U **[CBSE SQP 2017]**

**Ans. (i)** $Cr_2O_7^{2-}$ **[1]**

**(ii)** Cerium **[1]**

**Q. 3. Identify the following :**

**(i) Transition metal of 3d series that exhibits the maximum number of oxidation states.**

**(ii) An alloy consisting of approximately 95% lanthanoid metal used to produce bullet, shell and lighter flint.**

U **[CBSE Comptt. Delhi/OD 2018]**

**Ans. (i)** Mn **[1]**

**(ii)** Mischmetal **[1]**

**[CBSE Marking Scheme 2018]**

## Short Answer Type Questions-II

**(3 marks each)**

**Q. 1. Account for the following :**

**(i) $Eu^{2+}$ is a strong reducing agent.**

**(ii) Orange colour of dichromate ion changes to yellow in alkaline medium.**

**(iii) $E°(M^{2+}/M)$ values for transition metals show irregular variation.**

A&E **[CBSE Foreign Set-2 2017]**

**Ans. (i)** $Eu^{2+}$ is a strong reducing agent because $Eu^{3+}$ is more stable than $Eu^{2+}$. **[1]**

**(ii)** Dichromate ion changes to chromate ion/$OH^-$ **[1]**

$$Cr_2O_7^{2-} \text{ (orange)} \rightarrow CrO_4^{2-} \text{ (yellow)}$$

**(iii)** Due to the irregular variation in ionisation enthalpies (sum of [1]st and 2nd ionisation enthalpies), heat of sublimation and enthalpy of hydration/due to irregular electronic configurations from left to right in a period, which changes the ionisation potential.

**[CBSE Marking Scheme 2017] [1]**

**Detailed Answer :**

**(i)** Electronic configuration of $Eu^{2+}$ = $4f^7 6s^2$. On oxidation, the evolution of the electrons takes place. Hence, after the removal of 2 electrons it achieves stable half filled electronic configuration acting as a strong reducing agent.

**(ii)** $Cr_2O_7^{2-} + H_2O \rightleftharpoons 2Cr_2O_4^{2-} + 2H^+$

(Orange) (yellow)

When an alkali is added to an orange solution of dichromate, a yellow solution is obtained due to the formation of chromate ions.

**Q. 2. Explain the following :**

**(a) Out of $Sc^{3+}$, $Co^{2+}$ and $Cr^{3+}$ ions, only $Sc^{3+}$ is colourless in aqueous solutions. (Atomic no. Co = 27; Sc = 21 and Cr = 24)**

**(b) The $E°Cu^{2+}/Cu$ for copper metal is positive (+0.34), unlike the remaining members of the first transition series.**

**(c) $La(OH)_3$ is more basic than $Lu(OH)_3$.**

**A&E [CBSE SQP 2018-2019]**

**Ans. (a)** $Co^{2+}$ : $[Ar]3d^7$ $Sc^{3+}$ : $[Ar]3d^0$ $Cr^{3+}$ : $[Ar]3d^3$

$Co^{2+}$ and $Cr^{3+}$ have unpaired electrons. Thus, they are coloured in aqueous solution. $Sc^{3+}$ has no unpaired electron. Thus it is colourless. **[1]**

**(b)** Metal copper has high enthalpy of atomisation and enthalpy of ionisation. Therefore the high energy required to convert Cu(s) to $Cu^{2+}$(aq) is not balanced by its hydration enthalpy. **[1]**

**(c)** Due to lanthanoid contraction the size of lanthanoid ion decreases regularly with increase in atomic size. Thus covalent character between lanthanoid ion and $OH^-$ increases from $La^{3+}$ to $Lu^{3+}$. Thus the basic character of hydroxides decreases from $La(OH)_3$ to $Lu(OH)_3$. **[1]**

**[CBSE Marking Scheme 2018]**

**Q. 3. Give the reasons for following :**

**(i) Transition elements and their compounds acts as catalysts.**

**(ii) E° value for ($Mn^{+2}|Mn$) is negative whereas for ($Cu^{+2}|Cu$) is positive.**

**(iii) Actinoids show irregularities in their electronic configuration.** **R [CBSE Delhi Set 1 2019]**

**Ans. (i)** Due to variable oxidation state. **[1]**

**(ii)** $Mn^{2+}$ is stable due to exactly half filled $3d^5$ configuration/ Due to high $\Delta_aH^0$ and low $\Delta_{hy}dH^0$ for $Cu^{2+}/Cu$ is positive. **[1]**

**(iii)** Due to comparable energies of 5*f* , 6*d* and 7*s* orbitals.

**[CBSE Marking Scheme, 2019] [1]**

**Detailed Answer :**

**(i)** Transition metals have the ability to adsorb many other substances on their surface and activate them as a result of chemisorption. Transition metals also exhibit a variety of oxidation states, and can change oxidation states relatively easily. This makes transition metals and their compounds good catalysts.

**(ii)** $E^o$ values are indicative of the stability of the oxidized form of the element. The lower the $E^o$ value, more stable the oxidized form of the element. $Mn^{2+}$ with a half filled d-subshell ($d^5$) is stable, so Mn is easily oxidized to $Mn^{2+}$, making the $E^o$ value negative. $Cu^{2+}$ with a partially filled d subshell ($d^9$) is not stable, and is relatively easily reduced to element form. This makes its $E^o$ value positive.

**(iii)** The electronic configurations of actinoids show irregularities because the energies of their 5*f*, 6*d*, and 7*s* orbitals are close to each other. Electrons can easily move between these subshells.

**Q. 4. Give reasons for the following :**

**(i) Transition metals form alloys.**

**(ii) $Mn_2O_3$ is basic whereas $Mn_2O_7$ is acidic.**

**(iii) $Eu^{2+}$ is a strong reducing agent.**

**R [CBSE Delhi Set 2 2019]**

**Ans. (i)** Due to comparable radii / comparable size. **[1]**

**(ii)** In $Mn_2O_3$, Mn is in +3 (lower) oxidation state while in $Mn_2O_7$, Mn is in higher oxidation state (+7) **[1]**

**(iii)** Because its stable oxidation state is +3.

**[CBSE Marking Scheme, 2019] [1]**

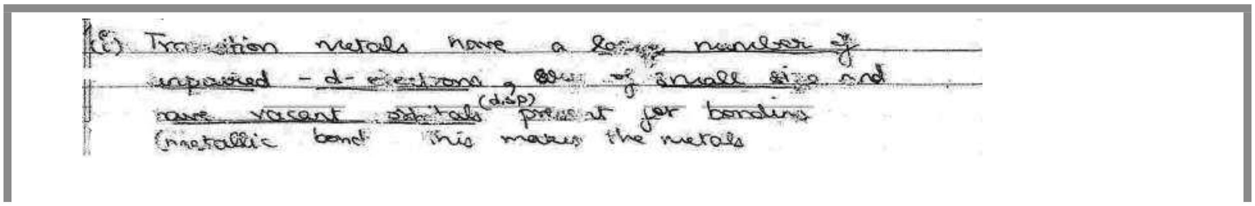
**Detailed Answer :**

**(i)** Transition metals easily form alloys with other transition metals because they have almost similar size. So they can easily replace each other in the crystal lattice.

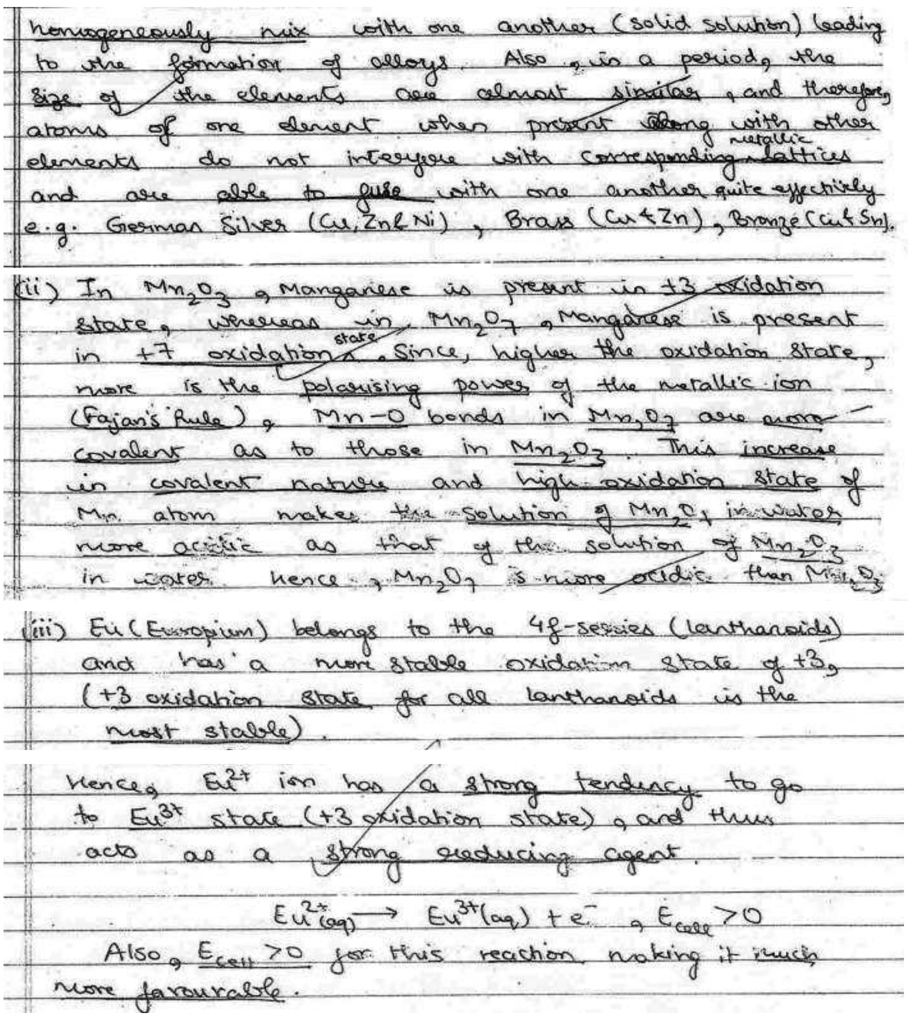
**(ii)** The transition metal oxides in the lower oxidation state of metals are basic in nature and in higher oxidation state they are acidic in nature. The oxidation state of Mn in $Mn_2O_3$ is +3 and $Mn_2O_7$ has +7. Therefore, $Mn_2O_3$ is basic and $Mn_2O_7$ is acidic.

**(iii)** The common oxidation state of lanthanide metals is +3. $Eu^{2+}$ is formed by losing the two s electrons acquires half filled ($4f^7$) configuration. But still, they oxidize to their common +3 state. So the $Eu^{2+}$ loses one electron and is oxidized to $Eu^{3+}$. So, $Eu^{2+}$ acts as a strong reducing agent.

**OR**



(i) Transition metals have a large number of unpaired - d- electrons, are of small size and have vacant orbitals (d,s,p) present for bonding (metallic bond) this makes the metals



homogeneously mix with one another (solid solution) leading to the formation of alloys. Also, in a period, the size of the elements are almost similar, and therefore, atoms of one element when present along with other elements do not interfere with corresponding metallic lattices and are able to fuse with one another quite effectively e.g. German Silver (Cu, Zn & Ni), Brass (Cu & Zn), Bronze (Cu & Sn).

(ii) In $Mn_2O_3$, Manganese is present in +3 oxidation state, whereas in $Mn_2O_7$, Manganese is present in +7 oxidation state. Since, higher the oxidation state, more is the polarising power of the metallic ion (Fajan's Rule), Mn–O bonds in $Mn_2O_7$ are more covalent as to those in $Mn_2O_3$. This increase in covalent nature and high oxidation state of Mn atom makes the solution of $Mn_2O_7$ in water more acidic as that of the solution of $Mn_2O_3$ in water. hence, $Mn_2O_7$ is more acidic than $Mn_2O_3$

(iii) Eu (Europium) belongs to the 4f-series (lanthanoids) and has a more stable oxidation state of +3, (+3 oxidation state for all lanthanoids is the most stable).

Hence, $Eu^{2+}$ ion has a strong tendency to go to $Eu^{3+}$ state (+3 oxidation state), and thus acts as a strong reducing agent.

$$Eu^{2+}_{(aq)} \longrightarrow Eu^{3+}(aq) + e^-, \ E_{cell} > 0$$

Also, $E_{cell} > 0$ for this reaction making it much more favourable.

**[Topper's Answer 2019] [3]**

**Q. 5. Give reasons for the following :**

**(a) Transition metals have high enthalpies of atomization.**

**(b) Manganese has lower melting point even though it has a higher number of unpaired electrons for bonding.**

**(c) $Ce^{4+}$ is a strong oxidizing agent.**

**R [CBSE OD Set 3 2019]**

**Ans. (i)** Because of strong interatomic interactions / Strong metallic bonding between atoms. **[1]**

**(ii)** Due to stable $3d^5$ configuration, interatomic interaction is poor between unpaired electrons. **[1]**

**(iii)** Because Ce is more stable in +3 oxidation state. **[CBSE Marking Scheme, 2019] [1]**

**Detailed Answer :**

**(a)** The transition elements have high enthalpies of atomization because they have large number of unpaired electrons in their atoms. This results in stronger interatomic interaction and stronger bonding between atoms.

**(b)** Mn has low melting point because of $3d^5 4s^2$ configuration, which is highly stable and delocalised, so are not available for bonding, as a result interatomic forces becomes weaker. Hence Mn has low melting point bounded half-filled a orbital electrons with nucleus results in strong interatomic interaction.

**(c)** The formation of $Ce^{4+}$ is promoted by its noble gas configuration reverting to the common +3 state. E° value for $Ce^{4+}/Ce^{3+}$ is + 1.74 V thus readily gains an electron and acts as a strong oxidizing agent.

**Q. 6. (a) When a chromite ore (A) is fused with an aqueous solution of sodium carbonate in free excess of air, a yellow solution of compound (B) is obtained. This solution is filtered and acidified with sulphuric acid to form compound (C). Compound (C) on treatment with solution of KCl gives orange crystals of compound (D). Write the chemical formulae of compounds A to D.**

**(b) Describe the cause of the following variations with respect to lanthanoids and actinoids :**

**(i) Greater range of oxidation states of actinoids as compared to lanthanoids.**

**(ii) Greater actinoid contraction as compared to lanthanoid contraction.**

**(iii) Lower ionisation enthalpy of early actinoids as compared to the early lanthanoids.**

**Ans. (a)** A = $FeCr_2O_4$  B = $Na_2CrO_4$  C = $Na_2Cr_2O_7$
D = $K_2Cr_2O_7$ **[½ × 4]**

**(b) (i)** 5f, 6d and 7s levels in actinoids are of comparable energies. **[1]**

**(ii)** This is due to poorer shielding by 5f electrons in actinoids as compared to shielding by 4f electrons in lanthanoids. **[1]**

**(iii)** In actinoids, 5f electrons are more effectively shielded from the nuclear charge than the 4f electrons of the corresponding lanthanoids. Since the outer electrons are less firmly held, they are available for bonding in the actinoids. **[1]**

**Q. 7. (a) What happens when**

**(i) Manganate ions ($MnO_4^{2-}$) undergoes disproportionation reaction in acidic medium?**

**(ii) Lanthanum is heated with sulphur?**

**(b) Explain the following trends in the properties of the members of the First series of transition elements :**

**(i) $E^0$ ($M^{2+}/M$) value for copper is positive (+0.34 V) in contrast to the other members of the series.**

**(ii) $Cr^{2+}$ is reducing while $Mn^{3+}$ is oxidising, though both have $d^4$ configuration.**

**(iii) The oxidising power in the series increases in the order $VO_2^+ < Cr_2O_7^{2-} < MnO_4^-$.**

**A [CBSE SQP 2020]**

**Ans. (a) (i)** $MnO_4^{2-}$ ions disproportionate in acidic medium to give permanganate ions and manganese(IV) oxide. **[½]**

$$3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O \quad [½]$$

**(ii)** Lanthanum sulphide if formed. **[½]**

$$2La + 3S \xrightarrow{\text{heat}} La_2S_3 \quad [½]$$

(Deduct overall ½ mark if equation not balanced/ statements not written)

**(b) (i)** Copper has high enthalpy of atomisation and low enthalpy of hydration, thus the high energy is required to transform Cu(s) to $Cu^{2+}$(aq) which is not balanced by hydration enthalpy, therefore $E^o(M^{2+} / M)$ value for copper is positive (+0.34 V). **[1]**

**(ii)** $Cr^{2+}$ is reducing as its configuration changes from $d^4$ to $d^3$, the latter having more stable half filled $t_{2g}$ level. On the other hand, the change from $Mn^{3+}$ to $Mn^{2+}$ results an extra stable $d^5$ configuration. **[1]**

**(iii)** This is due to the increasing stability of the species of lower oxidation state to which they are reduced. **[1]**

**Q. 8. Give reasons for the following :**

**(a) Transition metals form complex compounds.**

**(b) $E^o$ values for ($Zn^{2+}/Zn$) and ($Mn^{2+}/Mn$) are more negative than expected.**

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

**R [CBSE OD Set 1 2019]**

**Ans. (i)** Due to small size, high ionic charge and availability of *d*-orbital. [1]

**(ii)** Due to stable $3d^{10}$ configuration in $Zn^{2+}$ and $3d^5$ configuration in $Mn^{2+}$. **[1]**

**(iii)** Due to comparable energies of 5*f*, 6*d* and 7*s* orbitals / levels. **[1]**

**[CBSE Marking Scheme, 2019]**

**Detailed Answer :**

**(a)** Transition metals are able to form complex compounds due to the small size of metal, high ionic charge and availability of vacant *d*-orbital.

**(b)** E° values of ($Mn^{2+}/Mn$) and ($Zn^{2+}/Zn$) are more negative than expected due to the greater stability of half filled *d*-subshell of $Mn^{2+}(3d^5)$ and completely filled *d*-subshell of $Zn^{2+}(3d^{10})$.

**(c)** Due to a very small energy gap between 5*f*, 6*d* and 7s subshells resulting in easier excitation of the outermost electrons to higher energy levels.

## Long Answer Type Questions

**(5 marks each)**

**Q. 1. (i) Account for the following :**

**(a) Mn shows the highest oxidation state of +7 with oxygen but with fluorine it shows the highest oxidation state of +4.**

**(b) Zirconium and Hafnium exhibit similar properties.**

**(c) Transition metals act as a catalysts. (Atomic nos. : Mn = 25, Cr = 24)**

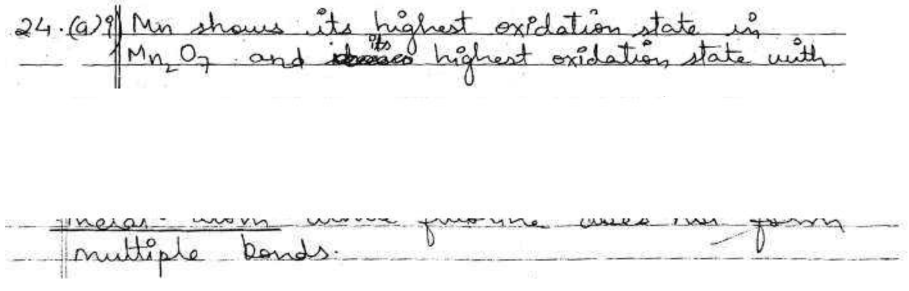
**(ii) Complete the following equations :**

**(a) $2MnO_2 + 4KOH + O_2 \xrightarrow{\Delta}$**

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

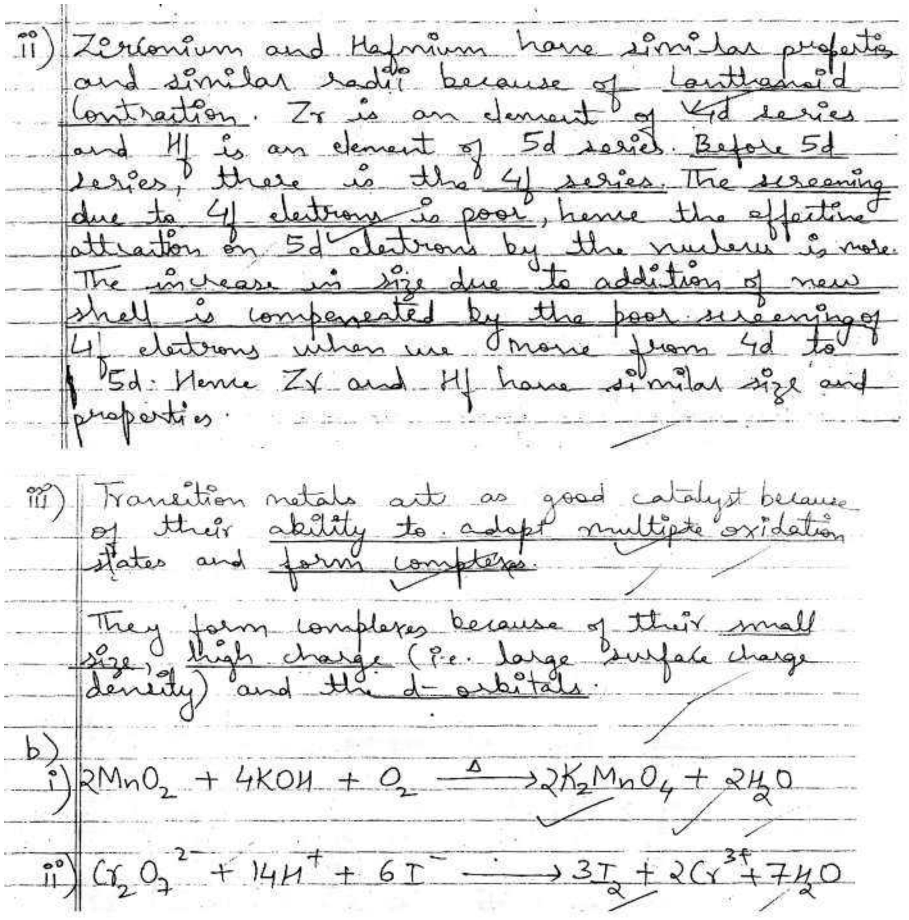
A&E + R

**Ans.**



24.(a)(i) Mn shows its highest oxidation state in $Mn_2O_7$ and ~~[illegible]~~ its highest oxidation state with

metal- [illegible] [illegible] fluorine [illegible] [illegible] form multiple bonds.



ii) Zirconium and Hafnium have similar propertis and similar radii because of Lanthanoid Contraction. Zr is an element of 4d series and Hf is an element of 5d series. Before 5d series, there is the 4f series. The screening due to 4f electrons is poor, hence the effective attraction on 5d electrons by the nucleus is more. The increase in size due to addition of new shell is compensated by the poor screening of 4f electrons when we move from 4d to 5d. Hence Zr and Hf have similar size and properties.

iii) Transition metals act as good catalyst because of their ability to adopt multiple oxidation states and form complexes.

They form complexes because of their small size, high charge (i.e. large surface charge density) and the d-orbitals.

b)

i) $2MnO_2 + 4KOH + O_2 \xrightarrow{\Delta} 2K_2MnO_4 + 2H_2O$

ii) $Cr_2O_7^{2-} + 14H^+ + 6I^- \longrightarrow 3I_2 + 2Cr^{3+} + 7H_2O$

**[Topper's Answer 2016] [5]**

**Q. 2. The elements of 3d transition series are given as :**

**Sc Ti V Cr Mn Fe Co Ni Cu Zn**

**Answer the following :**

**(i) Write the element which is not regarded as a transition element. Give reason.**

**(ii) Which element has the highest m.p?**

**(iii) Write the element which can show an oxidation state of +1.**

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

A **[CBSE OD Set-2 2016]**

**Ans. (i)** Zn , because it does not have partially filled *d*-orbital in its ground state or ionic state. **[1½]**

**(ii)** Cr has the highest melting point. As the number of unpaired electrons increases upto $d^5$ configuration, it results in the increase in the strength of metallic bonds. To break the metallic bond, significant energy is required thus Cr with highest number of unpaired electrons *i.e.*, 6 has the highest melting point. **[1]**

**(iii)** Cu can show +1 oxidation state as it can loose one electron present in 4s orbital. **[1]**

**(iv)** Mn is a strong oxidising agent in +3 oxidation state because change of $Mn^{3+}$ to $Mn^{2+}$ give stable half filled ($d^5$) configuration. **[1½]**

**Commonly Made Error**

- Students miss out on sub questions. Read and answer all sub questions carefully.

**Answering Tips**

- Comprehend what is being asked before answering by reading the question carefully.
- Don't forget to answer further sub-parts of the questions.

**Q. 3. (i) Account for the following :**

**(a) Transition metals form large number of complex compounds.**

**(b) The lowest oxide of transition metal is basic whereas the highest oxide is amphoteric or acidic.**

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

**(ii) Write one similarity and one difference between the chemistry of lanthanoid and actinoid elements.**

U + A&E

**Ans. (i) (a)** Due to small size and high ionic charge/ availability of *d* orbitals. **[1]**

**(b)** Higher is the oxidation state higher is the acidic character/as the oxidation state of a metal increases, ionic character decreases **[1]**

**(c)** Because $Mn^{2+}$ has $d^5$ as a stable, configuration whereas $Cr^{3+}$ is more stable due to stable $t^3_{2g}$ **[1]**

**(ii)** Similarity-both are stable in +3 oxidation state/ both show contradiction/irregular electronic configuration (or any other suitable similarity) **[1]**

Difference–actinoids are radioactive and lanthanoids are not/actinoids show wide range of oxidation states but lanthanoids don't (or any other correct difference) **[1]**

**Q. 4. (i) (a) How is the variability in oxidation states of transition metals different from that of the *p*-block elements?**

**(b) Out of $Cu^+$ and $Cu^{2+}$, which ion is unstable in aqueous solution and why?**

**(c) Orange colour of $Cr_2O_7^{2-}$ ion changes to yellow when treated with an alkali. Why?**

**(ii) Chemistry of actinoids is complicated as compared to lanthanoids. Give two reasons.**

A&E **[CBSE Delhi Set-1, 2, 3 2017]**

**Ans. (i) (a)** In *p*-block elements the difference in oxidation state is 2 and in transition metals the difference is 1. **[1]**

**(b)** $Cu^+$, due to disproportionation reaction and low hydration enthalpy [½+½]

**(c)** Due to formation of chromate ion/$CrO_4^{2-}$ ion, which is yellow in colour **[1]**

**(ii)** Actinoids are radioactive, actinoids show wide range of oxidation states **[1+1]**

**[CBSE Marking Scheme 2017]**

**AI Q. 3. (i) Account for the following :**

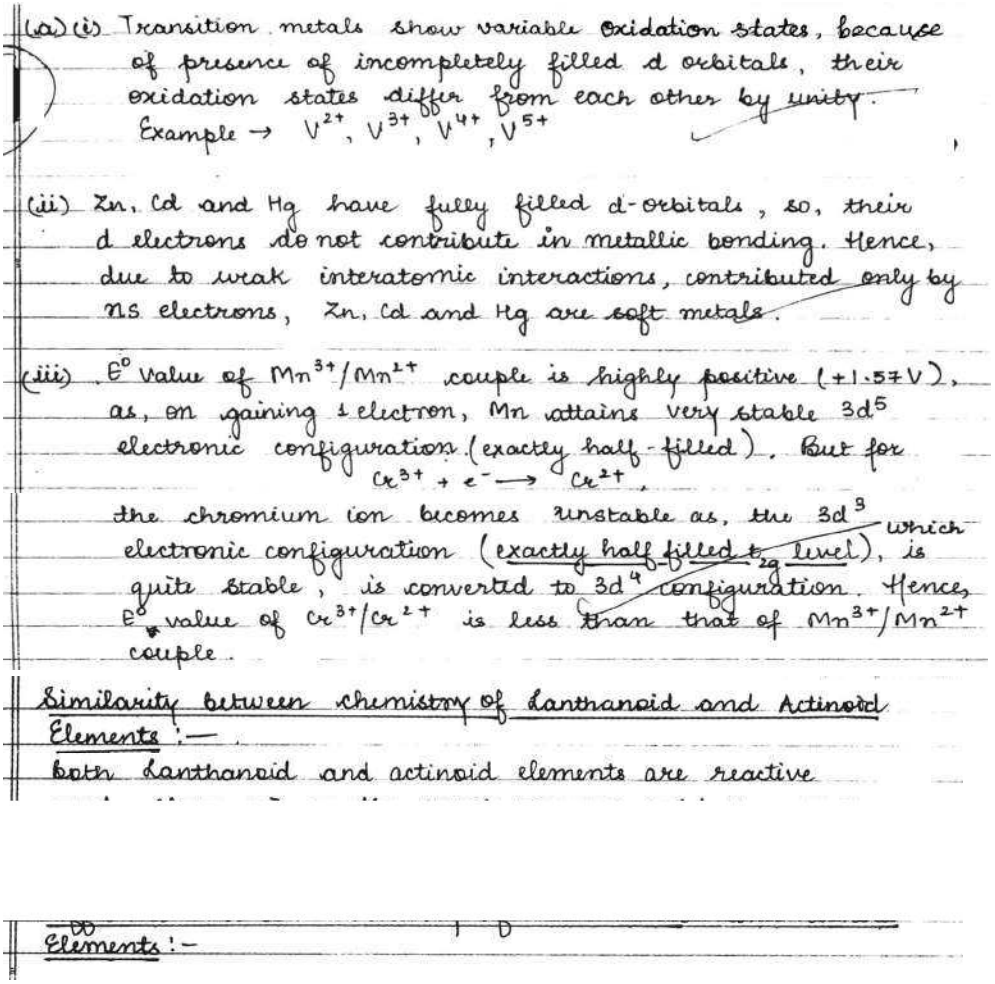
**(a) Transition metals show variable oxidation states.**

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

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

**(ii) Write one similarity and one difference between the chemistry of lanthanoid and actinoid elements.** A + E&U **[CBSE OD Set-1, 2, 3 2017]**

**Ans.**



(a) (i) Transition metals show variable Oxidation states, because of presence of incompletely filled d orbitals, their oxidation states differ from each other by unity.
Example → $V^{2+}, V^{3+}, V^{4+}, V^{5+}$

(ii) Zn, Cd and Hg have fully filled d-orbitals, so, their d electrons do not contribute in metallic bonding. Hence, due to weak interatomic interactions, contributed only by ns electrons, Zn, Cd and Hg are soft metals.

(iii) $E^0$ value of $Mn^{3+}/Mn^{2+}$ couple is highly positive (+1.57V), as, on gaining 1 electron, Mn attains very stable $3d^5$ electronic configuration (exactly half-filled). But for

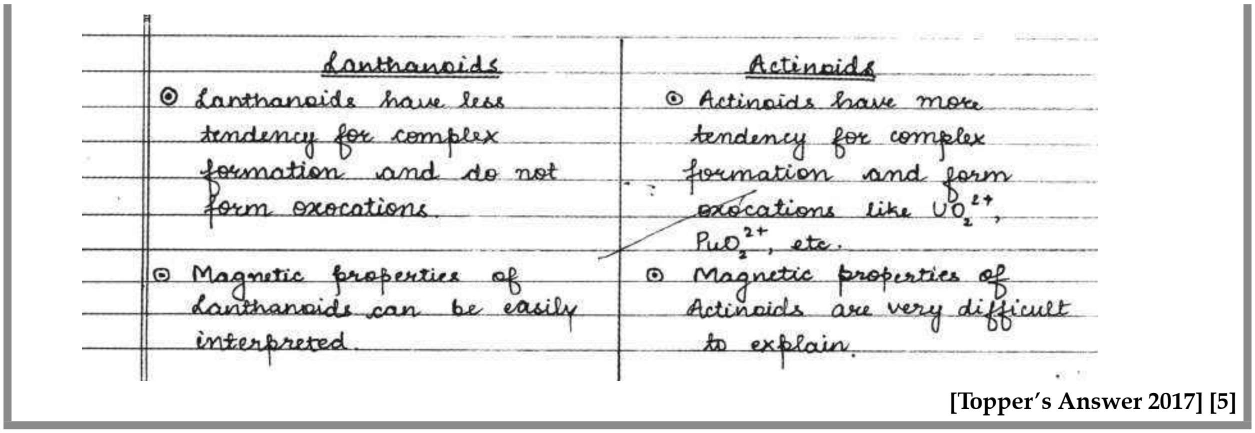
$$Cr^{3+} + e^- \longrightarrow Cr^{2+},$$

the chromium ion becomes unstable as, the $3d^3$ electronic configuration (exactly half filled $t_{2g}$ level), which is quite stable, is converted to $3d^4$ configuration. Hence, $E^0$ value of $Cr^{3+}/Cr^{2+}$ is less than that of $Mn^{3+}/Mn^{2+}$ couple.

Similarity between chemistry of Lanthanoid and Actinoid Elements :—

Both Lanthanoid and actinoid elements are reactive

Elements :–



| Lanthanoids | Actinoids |
|---|---|
| ⊙ Lanthanoids have less tendency for complex formation and do not form oxocations. | ⊙ Actinoids have more tendency for complex formation and form oxocations like $UO_2^{2+}$, $PuO_2^{2+}$, etc. |
| ⊙ Magnetic properties of lanthanoids can be easily interpreted. | ⊙ Magnetic properties of Actinoids are very difficult to explain. |

**[Topper's Answer 2017] [5]**

**Detailed Answer :**

**(i) (a)** The valence electrons of transition metals are in $(n-1)d$ and ns orbitals. As there is almost little energy difference between these orbitals, both the energy levels can be used for bond formation. Thus, they exhibit variable oxidation states.

**(b)** Because they contain fully filled *d*-orbitals, no unpaired d electrons are present resulting in weak metallic bonding.

**Q. 6. (i) (a) Which transition element in 3*d* series has positive $E^0_{M^{2+}/M}$ value and why?**

**(b) Name a member of lanthanoid series which is well known to exhibit +4 oxidation state and why?**

**(ii) Account for the following**

**(a) The highest oxidation state is exhibited in oxoanions of transition metals.**

**(b) HCl is not used to acidify $KMnO_4$ solution.**

**(c) Transition metals have high enthalpy of atomisation.**

A&E **[CBSE Comptt. Delhi Set-1, 2, 3 2017]**

**Ans. (i) (a)** Copper; Due to high $\Delta_g H^-$ and low $\Delta_{hyd} H^-$ [½+½]

**(b)** Cerium; Due to stable $4f^0$ configuration/Tb; Due to stable $4f^7$ configuration [½+½]

**(ii) (a)** Due to ability of oxygen to form multiple bonds to metal **[1]**

**(b)** HCl is oxidized to chlorine **[1]**

**(c)** Due to strong interatomic bonding **[1]**

**[CBSE Marking Scheme 2017]**

**Detailed Answer :**

**(ii) (a)** Due to high electronegativity and small size, oxygen acts as a strong oxidising agent. This results in oxygen's ability to oxidise the metal to attain highest oxidation state.

**(b)** As $KMnO_4$ is a very strong oxidising agent, it oxidizes HCl resulting in evolution of chlorine gas. Therefore, HCl is not used to acidify $KMnO_4$ solution.

**Q. 7. (a) Give reasons :**

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

**(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 $MnO_2$**

**Ans. (a) (i)** The catalytic activities of transition metals and their compounds is due to the ability of adopt variable oxidation states and to form complexes. It can also provide a large surface area for the reactants to be adsorbed. (Any one)

**(ii)** Separation of lanthanoid elements is difficult because all lanthanoid elements have almost similar physical as well as chemical properties. Due to the lanthanoid contraction the change in the atomic or ionic radii is very small.

**(iii)** Zn, Cd and Mg are soft and have low melting point because no *d*-orbitals are available for metallic bond formation and bonds formed are very weak.

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

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

**Q. 8. (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 :**

**$3MnO_4^2 + 4H^+ \rightarrow$**

U **[CBSE Delhi Set-1 2020]**

**Ans. (a) (i)** $Ti^{3+}$ has incomplete d ($3d^1$) orbital whereas $Sc^{3+}$ has empty (3d°) d-orbital.

**(ii)** $Cr^{2+}$ ion can lose electron to form $Cr^{3+}$, so acts as a strong reducing agent.

**(b) Similarities between chemistry of lanthanoids and actinoids :**

**(i)** Both show +3 oxidation state.

**(ii)** Both are strong reducing agents.

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

## Visual Case based Questions

**(4 marks each)**

**Q.1. Read the passage given below and answer the following questions :**

Within the 3d series, manganese exhibits oxidation states in aqueous solution from +2 to +7, ranging from $Mn^{2+}$(aq) to $MnO^{-}_4$ (aq). Likewise, iron forms both $Fe^{2+}$(aq) and $Fe^{3+}$(aq) as well as the $FeO^{2-}_4$ ion. Cr and Mn form oxyions $CrO^{2-}_4$, $MnO^{-}_4$, owing to their willingness to form multiple bonds. The pattern with the early transition metals—in the 3d series up to Mn, and for the 4d, 5d metals up to Ru and Os—is that the maximum oxidation state corresponds to the number of ''outer shell'' electrons. The highest oxidation states of the 3d metals may depend upon complex formation (e.g., the stabilization of $Co^{3+}$ by ammonia) or upon the pH (thus $MnO_4^{2-}$ (aq) is prone to disproportionation in acidic solution). Within the 3d series, there is considerable variation in relative stability of oxidation states, sometimes on moving from one metal to a neighbour; thus, for iron, $Fe^{3+}$ is more stable than $Fe^{2+}$, especially in alkaline conditions, while the reverse is true for cobalt. The ability of transition metals to exhibit a wide range of oxidation states is marked with metals such as vanadium, where the standard potentials can be rather small, making a switch between states relatively easy.

**(CBSE QB 2021)**

**(Cotton, S. A. (2011). Lanthanides: Comparison to 3d metals.** ***Encyclopedia of inorganic and Bio-inorganic Chemistry*****.)**

**In the following questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices on the basis of the above passage.**

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.**

**(i) Assertion:** Highest oxidation state is exhibited by transition metal lying in the middle of the series.

**Reason:** The highest oxidation state exhibited corresponds to number of (n−1)d electrons.

**(ii) Assertion:** $Fe^{3+}$ is more stable than $Fe^{2+}$

**Reason:** $Fe^{3+}$ has $3d^5$ configuration while $Fe^{2+}$ has $3d^6$ configuration.

**(iii) Assertion:** Vanadium had the ability to exhibit a wide range of oxidation states.

**Reason:** The standard potentials Vanadium are rather small, making a switch between oxidation states relatively easy.

**(iv) Assertion:** Transition metals like Fe, Cr and Mn form oxyions

**Reason:** Oxygen is highly electronegative and has a tendency to form multiple bonds.

**(v) Assertion:** The highest oxidation states of the 3d metals depends only on electronic configuration of the metal.

**Reason:** The number of electrons in the (n-1)d and ns subshells determine the oxidation states exhibited by the metal.

**Ans. (i)** Correct option : **(c)**

**(ii)** Correct option : **(a)**

**(iii)** Correct option : **(a)**

**(iv)** Correct option : **(b)**

**(v)** Correct option : **(d)**

**Q.2. Read the passage given below and answer the following questions :**

The transition metals when exposed to oxygen at low and intermediate temperatures form thin, protective oxide films of up to some thousands of Angstroms in thickness. Transition metal oxides lie between the extremes of ionic and covalent binary compounds formed by elements from the left or right side of the periodic table. They range from metallic to semiconducting and deviate by both large and small degrees from stoichiometry. Since d-electron bonding levels are involved, the cations-exist in various valence states and hence give rise to a large number of oxides. The crystal structures are often classified by considering a cubic or hexagonal close-packed lattice of one set of ions with the other set of ions filling the octahedral or tetrahedral interstices. The actual oxide structures, however, generally show departures from such regular arrays due in part to distortions caused by packing of ions of different size and to ligand field effects. These distortions depend not only on the number of d-electrons but also on the valence and the position of the transition metal in a period or group. (source: Smeltzer, W. W., & Young, D. J. (1975). Oxidation properties of transition metals. *Progress in Solid State Chemistry*, **10, 17-54.)**

**(CBSE QB 2021)**

**In the following questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices on the basis of the above passage.**

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.**

**(i) Assertion:** Cations of transition elements occur in various valence states

**Reason:** Large number of oxides of transition elements are possible.

**(ii) Assertion:** Crystal structure of oxides of transition metals often show defects.

**Reason:** Ligand field effect cause distortions in crystal structures.

**(iii) Assertion :** Transition metals form protective oxide films.

**Reason:** Oxides of transition metals are always stoichiometric.

**(iv) Assertion:** CrO crystallises in a hexagonal close-packed array of oxide ions with two out of every three octahedral holes occupied by chromium ions.

**Reason:** Transition metal oxide may be hexagonal close-packed lattice of oxide ions with metal ions filling the octahedral voids.

**Ans. (i)** Correct option : **(b)**

**(ii)** Correct option : **(a)**

**(iii)** Correct option : **(c)**

**(iv)** Correct option : **(d)**

**Q.3. Read the passage given below and answer the following questions :**

The d block elements are the 40 elements contained in the four rows of ten columns (3-12) in the periodic table. As all the d block elements are metallic, the term d-block metals is synonymous. This set of d-block elements is also often identified as the transition metals, but sometimes the group 12 elements (zinc, cadmium, mercury) are excluded from the transition metals as the transition elements are defined as those with partly filled d or f shells in their compounds. Inclusion of the elements zinc, cadmium and mercury is necessary as some properties of the group 12 elements are appropriate logically to include with a discussion of transition metal chemistry. The term transition element or transition metal appeared to derive from early studies of periodicity such as the Mendeleev periodic table of the elements. His horizontal table of the elements was an attempt to group the elements together so that the chemistry of elements might be explained and predicted. In this table there are eight groups labeled I-VIII with each subdivided into A and B subgroups. Mendeleev recognized that certain properties of elements in Group VIII are related to those of some of the elements in Group VII and those at the start of the next row Group I. In that sense, these elements might be described as possessing properties transitional from one row of the table to the next. *(source: Winter, M. J. (2015). D-block Chemistry (Vol. 27). Oxford University Press, USA.)*

**In the following questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices on the basis of the above passage.**

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.** **(CBSE QB 2021)**

**(i) Assertion:** Group 12 elements are not considered as transition metals.

**Reason:** Transition metals are those which have incompletely filled d shell in their compounds.

**(ii) Assertion:** All d block elements are metallic in nature.

**Reason:** The d –block elements belong to Group3 -12 of the periodic table.

**(iii) Assertion :** Group VII elements of Mendeleev periodic table are transition elements.

**Reason:** Group I –VIII in Mendeleev periodic table is divided into two subgroups, A and B.

**(iv) Assertion:** Nickel is a transition element that belongs to group 10 and period 4 of the modern periodic table.

**Reason:** Electronic configuration of Nickel is $[Ar]_{18}3d^8 4s^2$

**Ans. (i)** Correct option : **(a)**

**(ii)** Correct option : **(b)**

**(iii)** Correct option : **(d)**

**(iv)** Correct option : **(a)**

**Q.4. Read the passage given below and answer the following questions :** **(1 × 4 = 4)**

In transition elements, generally, ions of the same charge in a given series show progressive decrease in radius with increasing atomic number. This is because the new electron enters a d orbital each time the nuclear charge increases by unity. But the radii of the third (5d) series are virtually the same as those of the corresponding members of the second series. This phenomenon is associated with the intervention of the 4f orbitals which must be filled before the 5d series of elements begin. The filling of 4f before 5d orbital results in a regular decrease in atomic radii called Lanthanoid contraction.

**In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.**

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.**

**Following are the transition metal ions of 3d series : $Ti^{4+}$, $V^{2+}$, $Mn^{3+}$, $Cr^{3+}$**

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

**(i) Assertion :** Among the given ions, $Cr^{3+}$ is the most stable in an aqueous environment.

**Reason :** $Cr^{3+}$ has half filled $t^32g$.

**(ii) Assertion :** Among the given ions, $Mn^{3+}$ is the most strong oxidizing agent.

**Reason :** $Mn^{3+}$ has an unstable configuration.

**(iii) Assertion :** $Ti^{4+}$ ion is colourless.

**Reason :** All valence electrons are unpaired in $Ti^{4+}$ ion.

**(iv) Assertion :** Atomic radii of third series of transition elements is similar to that of the second series.

**Reason :** According to Aufbau's principle, 4f orbitals needs to be filled before the 5d series begin.

**Ans. (i) Correct option :** (d)

$Cr^{3+}$, half filled $t^32g$ **[½+½]**

**(ii) Correct option :** (c)

$Mn^{3+}$ is the strong oxidising agent because it has 4 electrons in its valence shell and when it gains one electron than it forms $Mn^{2+}$, it results in the half-filled ($d^5$) configuration that provides extra stability. **[½+½]**

**(iii) Correct option :** (a)

$Ti^{4+}$, No unpaired electrons **[½+½]**

**(iv) Correct option : (b)**

Lanthanoid contraction **[1]**

**Q.5. Read the passage given below and answer the following questions : (1 × 4 = 4)**

Although actinoids are similar to lanthanoids in that their electrons fill the 5f orbitals in order, their chemical properties are not uniform and each element has characteristic properties. Promotion of 5f - 6d electrons does not require a large amount of energy and examples of compounds with ππ-acid ligands are known in which all the 5f, 6d, 7s, and 7p orbitals participate in bonding. Trivalent compounds are the most common, but other oxidation states are not uncommon. Especially thorium, protactinium, uranium, and neptunium tend to assume the +4 or higher oxidation state.

**The following questions are multiple choice questions. Choose the most appropriate answer :**

**(i) Which of the following oxidation state is common for all lanthanoids?**

**(a)** +2 **(b)** +3

**(c)** +4 **(d)** +5

**(ii) There are 14 elements in actinoid series. Which of the following element does not belong to this series?**

**(a)** U **(b)** Np

**(c)** Tm **(d)** Fm

**(iii) General electronic configuration of actinoids is $(n-2)f^{1-14}\,(n-1)d^{0-2}\,ns^2$. Which of the following actinoids have one electron in 6d orbital?**

**(a)** U (Atomic no. 92) **(b)** Np (Atomic no.93)

**(c)** Pu (Atomic no. 94) **(d)** Bk (Atomic no. 97)

**(iv) Gadolinium belongs to 4*f* series. Its atomic number is 64. Which of the following is the correct electronic configuration of gadolinium?**

**(a)** $[Xe]\ 4f^7 5d^1 6s^2$ **(b)** $[Xe]\ 4f^6 5d^2 6s^2$

**(c)** $[Xe]\ 4f^8 6d^2$ **(d)** $[Xe]\ 4f^9 5s^1$

**Ans. (i) Correct option : (b)**

*Explanation :* All of the lanthanide elements are commonly known to have the +3 oxidation state. **[1]**

**(ii) Correct option : (c)**

*Explanation :* Tm is Thulium which belongs to Lanthanoids. Uranium(U), Neptunium(Np), Fermium(Fm) belong to Actinoid series. **[1]**

**(iii) Correct option : (a)**

*Explanation :* Uranium has an electronic configuration of $5f^3\ 6d^1\ 7s^2$. **[1]**

**(iv) Correct option : (a)**

*Explanation :* Gadolinium has an electronic configuration of $[Xe]\ 4f^7 5d^1 6s^2$ **[1]**

**Q.6. Read the passage given below and answer the following questions : (1 × 4 = 4)**

Buffered aqueous solutions of potassium permanganate and sodium or potassium dichromate are used to remove completely traces of hydrogen sulfide from industrial gases. Processes employing such solutions are non-regenerative and, because of the high cost of the chemicals used, are only economical when very small amounts of hydrogen sulfide are present in the gas. Permanganate solutions are used quite extensively for the final purification of carbon dioxide in the manufacture of dry ice. The solution, which in the case of the permanganate process contains about 4.0% potassium permanganate and 1.0% sodium carbonate, is circulated until approximately 75% of the permanganate in either tower is converted to manganese dioxide.

**The following questions are multiple choice questions. Choose the most appropriate answer :**

**(i) $KMnO_4$ acts as an oxidizing agent in the acidic medium. The number of moles of $KMnO_4$ that will be needed to react with one mole of sulphide ion in acidic solution is :**

**(a)** 2/5 **(b)** 3/5

**(c)** 4/5 **(d)** 1/5

**(ii) $KMnO_4$ acts as an oxidising agent in alkaline medium. When alkaline $KMnO_4$ is treated with KI, iodide ion is oxidised to :**

**(a)** $I_2$ **(b)** $IO^-$

**(c)** $IO_3^-$ **(d)** $IO_4^-$

**(iii) Generally, transition elements and their salts are coloured due to the presence of unpaired electrons in metal ions. Which of the following compounds are coloured?**

**(a)** $KMnO_4$ **(b)** $TiCl_4$

**(c)** $Cu_2Cl_2$ **(d)** All of the above

**(iv) Why is HCl not used to make the medium acidic in oxidation reactions of $KMnO_4$ in acidic medium?**

**(a)** Both HCl and $KMnO_4$ act as oxidising agents.

**(b)** $KMnO_4$ oxidises HCl into $Cl_2$ which is also an oxidising agent.

**(c)** $KMnO_4$ is a weaker oxidising agent than HCl.

**(d)** $KMnO_4$ acts as a reducing agent in the presence of HCl.

**Ans. (i) Correct option : (a)**

*Explanation :* $2MnO_4^- + 5S^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 5S + 8H_2O$

For 5 moles of S the number of moles of $KMnO_4 = 2$

For 1 mole of S the number of moles of $KMnO_4 = 2/5$ **[1]**

**(ii) Correct option : (c)**

*Explanation :*

$2KMnO_4 + KI + H_2O \rightarrow 2KOH + 2MnO_2 + KIO_3$ **[1]**

**(iii) Correct option : (a)**

*Explanation :* $KMnO_4$ is dark purple crystalline compound. **[1]**

**(iv) Correct option : (a)**

*Explanation :* $KMnO_4$ oxidises HCl into $Cl_2$ which is also an oxidising agent. Hence HCl is not used in the oxidation reactions of $KMnO_4$ to make medium acidic. **[1]**

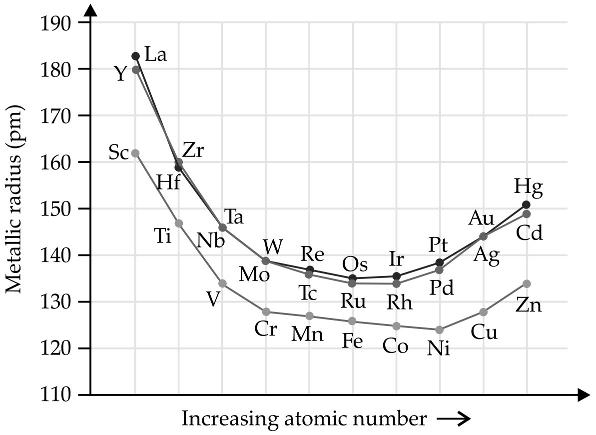
❑❑

# Self Assessment Test - 8

**Time : 1 Hour** **Max. Marks : 25**

1. **Read the passage given below and answer the following questions : (1 × 4 = 4)**

Trends in atomic radii of transition metals.



**The following questions are multiple choice questions. Choose the most appropriate answer.**

**(i) Metallic radii of some transition elements are given below. Which of these elements will have highest density?**

| Element | Fe | Co | Ni | Cu |
|---|---|---|---|---|
| Metallic radii/pm | 126 | 125 | 125 | 128 |

**(a)** Fe **(b)** Ni

**(c)** Co **(d)** Cu

**(ii) Although Zirconium belongs to 4d transition series and Hafnium to 5*d* transition series even then they show similar physical and chemical properties because :**

**(a)** both belong to d-block.

**(b)** both have same number of electrons.

**(c)** both have similar atomic radius.

**(d)** both belong to the same group of the periodic table.

**(iii) The second and third rows of transition elements resemble each other much more than they resemble the first row.**

**(a)** The statement is true.

**(b)** Initial elements of second and third rows resemble each other.

**(c)** Initial elements of first and second rows resemble each other.

**(d)** The statement is false.

**(iv) Which of the following statements is not correct?**

**(a)** Copper liberates hydrogen from acids.

**(b)** In its higher oxidation states, manganese forms stable compounds with oxygen and fluorine.

**(c)** $Mn^{3+}$ and $Co^{3+}$ are oxidising agents in aqueous solution.

**(d)** $Ti^{2+}$ and $Cr^{2+}$ are reducing agents in aqueous solution.

2. **Read the passage given below and answer the following questions : (1 × 4 = 4)**

The Lanthanide ions that have unpaired electrons are coloured and are paramagnetic. In several aspects, the magnetic and spectral behaviour of lanthanides is fundamentally different from that of the difference lies in the fact that the electrons responsible for the magnetic and spectral properties of lanthanide ions are 4f electrons , and the 4f orbitals are very effectively shielded from interaction with external forces by the over lying $6s^2$ and $6p^6$ shells. Hence, there are essentially only very weak effects of ligand fields. Hence the states arising from the various $4f^n$ configurations are only slightly affected by the surroundings of the ions and remain practically invariant for a given ion in all of its compounds.

Choose the correct answer out of the following choices.

**(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**

**(b) Assertion and reason both are correct statements but reason is not the correct explanation for assertion.**

**(c) Assertion is correct statement but reason is wrong statement.**

**(d) Assertion is wrong statement but reason is correct statement.**

**(i) Assertion :** Cerium also shows +4 oxidation state.

**Reason :** Characteristic oxidation state of lanthanoids is +3.

**(ii) Assertion :** The lanthanoid contraction leads to overall decrease of atomic and ionic radii from lanthanum to lutetium.

**Reason :** The filling of 4f before 5d orbitals result in decrease of atomic radii.

**(iii) Assertion :** The magnetic moment of $Cr^{3+}$ is 3.87 B.M. and that of $Co^{2+}$ is 4.87 B.M.

**Reason :** $Cr^{3+}$ and $Co^{2+}$ ions have same number of unpaired electrons.

**(iv) Assertion :** Ionisation enthalpies of Ce, Pr and Nd are higher than Th, Pa and U.

**Reason :** Outer electrons are tightly held in actinoids as compared to lanthanoids.

**Q.3. Transition elements form binary compounds with halogens. Which of the following elements will form $MF_3$ type compounds?**

**(i)** Co **(ii)** Cu **(iii)** Ni

**In the following question (Q. No. 4) a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.**

- **(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.**
- **(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.**
- **(c) Assertion is correct statement but reason is wrong statement.**
- **(d) Assertion is wrong statement but reason is correct statement.**

**Q.4. Assertion :** Actinoids form relatively less stable complexes as compared to lanthanoids.

**Reason :** Actinoids can utilise their 5f orbitals along with 6d orbitals in bonding but lanthanoids do not use their 4f orbitals for bonding.

**Q.5. Give reasons for the following :**

**(i)** Transition metals have high enthalpies of atomization.

**(ii)** Manganese has lower melting point even though it has a higher number of unpaired electrons for bonding.

**AI Q.6. Complete and balance the following chemical equations :**

**(a)** $SO_3^{2-} + MnO_4^- + H^+ \rightarrow Mn^{2+} + H_2O + SO_4^{2-}$

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

**Q.7. Give reason for the following :**

**(a)** Compounds of transition elements are generally coloured.

**(b)** MnO is basic while $Mn_2O_7$ is acidic.

**(c)** Many of the transition elements are known to form interstitial compounds.

**Q.8. The sum of first and second ionization energies and sum of third and fourth ionization energies of Nickel and Platinum are given as below:**

| | $IE_1 + IE_2$ (kJ $mol^{-1}$) | $IE_3 + IE_4$ (kJ $mol^{-1}$) |
|---|---|---|
| Ni | 2.49 | 8.80 |
| Pt | 2.66 | 6.70 |

**By considering these values, state the following :**

**(i)** Most stable oxidation states of Ni and Pt and its cause.

**(ii)** Name the metal which easily forms compounds in +4 oxidation state and why?

**(iii) $Cr^{3+}$ is a stronger reducing agent than $Fe^{2+}$.**

**Q.9. (i) Account for the following :**

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

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

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

**(ii) (a)** Complete the following equation :

$MnO_4^- + 8H^+ + 5e^- \rightarrow$

**(b)** Out of $Mn^{3+}$ and $Cr^{3+}$, which is more paramagnetic and why ?

(Atomic nos. : Mn = 25, Cr = 24)