# The d and f-Block Elements

## SOLUTIONS

### EXERCISE - O

**1.** **Ans. (A)**

Transition elements having more tendency to form complex due to availability of d-orbitals. In comnplex, transition element can accept electron cloud from ligands into its vacant d-orbitals through coordinate bond.

**2.** **Ans. (B)**

$_{30}Zn$ : [Ar] $4s^2$ $3d^{10}$

Zinc has fully filled (n – 1)d subshell means $3d^{10}$ and ns subshell means 4s-subshell is also full if zinc remove $2e^{\ominus}$ electrons then it will achieve fully filled ($3d^{10}$) electronic configuration which is also stable.

**3.** **Ans. (B)**

Mercury (Hg) is exist in liquid form at room temperature

**4.** **Ans. (D)**

Cu, Ag and Au metals are known as coinage metals and they show properties of transition element

**5.** **Ans. (A)**

Fluorine and oxygen atoms are most electronegative element and small in size. They have ability to stabilise the highest oxidation state is due to higher lattice energy or higher bond enthalpy

**6.** **Ans. (C)**

Valence shell electronic configuration of transition metal is ns and (n – 1)d subshell and electrons of both subshell are participating in bond formation i.e. they show variable oxidation state.

**7.** **Ans. (A)**

Metre scale are made-up of invar alloy(It is a type of steel in which 36% Ni is present).

**8.** **Ans. (A)**

Cr : [Ar] $3d^5 4s^1$

The highest oxidation state of Cr is +6 because all electrons of 4s($n_s$) and 3d((n – 1)d) can participating in bond formation

**9.** **Ans. (C)**

Zn : [Ar]$3d^{10}$ $4s^2$

In Zn, outer most shell is 4 which is not completely filled because $4^{th}$ shell contain 4s, 4p, 4d and 4f subshell.

**10.** **Ans. (C)**

Tungsten is a element not a compound

**11.** **Ans. (B)**

HgS is used in cosmetics and it is also known as Vermilion

**12.** **Ans. (B)**

$MnO_4^{\ominus}$ is of purple colour, through Mn is in + 7 oxidation state ($3d^0$), it is due to charge transfer when oxygen gives its electron to $Mn^{7\oplus}$ into $Mn^{6\oplus}$ temporarily

**13. Ans. (A)**

$MnO_4^{\ominus} + 5C_2O_4^{2\ominus} + 16H^{\oplus} \longrightarrow 2Mn^{2\oplus} + 8H_2O + 10CO_2$

(Purple sol$^n$) (Colour less sol$^n$.)

in this reaction, self indicator is $MnO_4^-$ because during the reaction, it will decolourised.

**14. Ans. (A)**

$$CrO_4^{2\ominus} + 2H_2O_2 + 2H^{\oplus} \xrightarrow[\text{Solvent}]{\text{Organic}} \underset{\text{(X)}}{\underset{\text{(Blue)}}{CrO_5}} + \underset{\text{(Y)}}{3H_2O}$$

**15. Ans. (C)**

$2KMnO_4 + 16HCl \rightarrow 2MnCl_2 + 2KCl + 5Cl_2\uparrow + 8H_2O$

(Greenish yellow gas)

**16. Ans. (B)**

$KMnO_4$ is purple in colour due to charge transfer from oxygen to $Mn^{+7}$ oxidation state

$Mn^{7+}$ : [Ar]3d°

**17. Ans. (B)**

$K_2CrO_4$ is yellow in colour due to charge transfer from oxygen to $Cr^{6\oplus}$,

In $CrO_4^{2\ominus}$ : Hyb : $d^3s$

Shape : Tetrahedral

**18. Ans. (B,C,D)**

When boron and carbon occupy interstitial sites of a transition metal then overall mass increased but volume of that particular lattice remains constant i.e. density increased, hardness increased but malleability and ductility decreased.

**19. Ans. (A,B)**

Due to very high ionisation of mercury, it cannot form ionic compound and due to weak metallic bond it exist as a liquid not solid

**20. Ans. (A,B)**

Ionisation energy

order in a period: S-block < d-block < p-block

(In general) Because from left to right zeff increases.

**21. Ans. (B,C)**

Highest oxidation state among transition elements are shown by Os on Ru which is +8

**22. Ans. (A,B,C)**

The catalytic properties of transition elements is related to their variable oxidation state, complex formation tendency and free surface for formation of bonds between reactant molecules and atoms of the surface of the catalyst.

**23. Ans. (A,B,C)**

d-block elements like Fe, Co, Ni can form interstitial compounds

**24. Ans. (A,B)**

Due to lanthanide contraction, Zr(4d) and Hf(5d) have same atomic size and same properties

**25.** **Ans. (A,B)**

$MnO \rightarrow$ Basic

$MnO_2 \rightarrow$ Amphoteric

$Mn_3O_4 \equiv 2MnO \cdot MnO_2 \rightarrow$ Amphoteric

$Mn_2O_7 \rightarrow$ Acidic

**26.** **Ans. (A,B,C)**

(A) $\underset{\text{(Purple)}}{MnO_4^{\ominus}} + SO_2 \xrightarrow{H^{\oplus}} \underset{\text{(Colourless)}}{Mn^{2\oplus}} + SO_4^{2\ominus} + H_2O$

(B) $MnO_4^{\ominus} + H_2O_2 \xrightarrow{H^{\oplus}} Mn^{2\oplus} + O_2\uparrow + H_2O$

(C) $MnO_4^{\ominus} + Fe^{2\oplus} \xrightarrow{H^{\oplus}} Mn^{2\oplus} + Fe^{3\oplus}$

(D) $MnO_4^{\ominus} + \overset{+3}{Fe}_2(\overset{+6}{SO_4})_3 \xrightarrow{H^{\oplus}}$ No reaction

**27.** **Ans. (D)**

All are correct (Information based)

**28.** **Ans. (B)**

| Ion | u.p.e$^{\ominus}$ | | |
|---|---|---|---|
| $V^{5\oplus}$ : | $[Ar]3d^0$ | 0 | Diamagnetic |
| $V^{4\oplus}$ : | $[Ar]3d^1$ | 1 | Paramagnetic |
| $O^{2\ominus}$ : | $[He]2S^22p^6$ | 0 | Diamagnetic |
| $VO_3^{\ominus}$ : | V5+:$[Ar]3d^0$ | 0 | Diamagnetic |

**29.** **Ans. (C)**

**30.** **Ans. (A)**

**Sol for 29 and 30**

When boron and carbon occupy interstitial sites of a transition metal then overall mass increased but volume of that particular lattice remains constant i.e. density increased, hardness increased but malleability and ductility decreased while electrical conductance and metallic lustre remains same.

**31.** **Ans. (D)**

(A) Highest oxidation state of 3d-series is +7 which is shown by Mn.

(B) Ni and Cu are transition element but Zn does not.

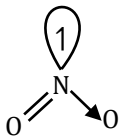
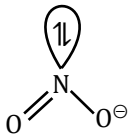
(C) Ziglar natta catalyst: $TiCl_3$

(D)

| Ion | Colour of aq. son$^n$. |
|---|---|
| $Cu^{2\oplus}$ | Blue |
| $Fe^{3\oplus}$ | Yellow |
| $Cr^{3\oplus}$ | Green |

## EXERCISE - S

**1. Ans. (003)**

| Species | | | u.p.e$^{\ominus}$. | Magnetic moment |
|---|---|---|---|---|
| $Fe^{2\oplus}$ | : | $[Ar]3d^6$ | 4 | 4.90 B.M. |
| $Cu^{2\oplus}$ | : | $[Ar]3d^9$ | 1 | 1.73 B.M. |
| $Ni^{2\oplus}$ | : | $[Ar]3d^8$ | 2 | 2.84 B.M. |
| $NO_2$ | : |  | 1 | 1.73 B.M. |
| $NO_2^{\ominus}$ | : |  | 0 | 0 |
| $Ti^{3\oplus}$ | : | $[Ar]3d^1$ | 1 | 1.73 B.M. |

**2. Ans. (2)**

Two elements of 3d-series (Mn, Cr) have $d_5$ configuration.

**3. Ans. (5)**

$$SO_2 + \frac{1}{2}O_2 \xrightarrow{V_2O_5} SO_3$$

**4. Ans. (0008)**

| Group | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3d series | Sc | Ti | **V** | Cr | Mn | Fe | Co | Ni | Cu | Zn |
| 4d series | Y | Zr | **Nb** | Mo | **Tc** | **Ru** | **Rh** | **Pd** | Ag | Cd |
| 5d series | La | Hf | Ta | **W** | Re | Os | Ir | **Pt** | Au | Hg |

Nb-[Kr] $5s^14d^4$ W-[Xe] $6s^25d^4$

Tc-[Kr] $5s^14d^6$ Ru-[Kr] $5s^14d^7$

Rh-[Kr] $5s^14d^8$ Pd-[Kr] $5s^04d^{10}$

Pt-[Xe] $6s^15d^9$ V-[Ar] $4s^23d^3$

**5. Ans. (0009)**

In +3, +4 & +7 O.S. Sc, Ti & Mn respectively form $Sc_2O_3$, $TiO_2$ & $Mn_2O_7$

Oxocations stabilise $V^{5\oplus}$ as $VO_2^{\oplus}$, $V^{4\oplus}$ as $VO^{2\oplus}$ and $Ti^{4\oplus}$ as $TiO^{2\oplus}$

The tetrahedral $[MO_4]^{n\ominus}$n ions are known for $V^{5\oplus}$, $Cr^{6\oplus}$, $Mn^{5\oplus}$, $Mn^{6\oplus}$ and $Mn^{7\oplus}$

Ferrate $FeO_4^{2\ominus}$ are formed in alkaline medium and readily decompose

**6. Ans. (0007)**

$TiF_2$, $TiBr_2$ does not exist.

**7. Ans. (0003)**

Cu in +2 O.S., can form halides only with F and Cl

Cu in +1 O.S., can form halides with Cl, Br and I

**8.** **Ans. (6)**

$$4NaCl + K_2Cr_2O_7 + 6H_2SO_4 \xrightarrow{\Delta} 2KHSO_4 + \underset{(X)}{2\overset{+6}{Cr}O_2Cl_2} + 4NaHSO_4 + 3H_2O$$

**9.** **Ans. (4)**

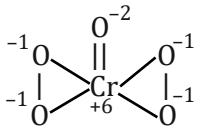
$MnO_4^{\ominus}$ is tetrahedral ion and there are four triangular faces in $MnO_4^{\ominus}$.

**10.** **Ans. (3)**

O.N. of Cr in X ($FeO \cdot Cr_2O_3$) = +3

O.N. of Cr in Z ($Na_2Cr_2O_7$) = +6

**11.** **Ans. (4)**




**12.** **Ans. (003)**

$MnO_4$, $Fe_3O_4$, $CO_3O_4$ are mixed oxides.

**13.** **Ans. (0002)**

Only $V_2O_5$ and $MnO_2$ are amphoteric

**14.** **Ans. (3)**

Actinides exhibit most common oxidation state of +3 like the lanthanoids because mostly of them can form compounds in +3 O.S.

**15.** **Ans. (3)**

59, 95, 102 are inner transition elements.

**16.** **Ans. (7)**

$Gd \rightarrow [Xe]\ 4f^7\ 5d^1\ 6s^2$

$Gd^{3\oplus} \rightarrow [Xe]\ 4f^7$

no. of unpaired $e^{\ominus}$ in $Gd^{3\oplus}$ = no of $e^{\ominus}$ present in 4f

= 7

## EXERCISE - JEE (Main) PYQ

**1. Ans. (1)**

In both Ruby ($Al_2O_3$) and Emerald [$Be_3Al_2(SiO_3)_6$] $Al^{3\oplus}$ ions are replaced by $Cr^{3\oplus}$ ions and due to d-d transition red and green colour shown in Ruby and Emerald respectively.

**2. Ans. (2)**

$MnO_4^{2\ominus}$ is stable in aqueous solution as +6 oxidation state of Mn is stable.

**3. Ans. (3)**

$Ti^{2\oplus}$ , $Cr^{2\oplus}$ and $V^{2\oplus}$ all three converts in their +3 o.s. in acidic medium because '+3' is stable o.s. for Ti, Cr and V so $H_2$ gas is obtained but due to half-filled configuration $Mn^{2\oplus}$ is very less reactive so it is not able to reduce $H^{\oplus}$ into $H_2$.

**4. Ans. (3)**

Due to half-filled stable electron configuration of Eu, electron present in 4f subshell don't participate in metallic bonding that's why atomic radii increases
we can refer the ncert data of atomic radii.

| Eu | > | Ce | > | Nd | > | Ho |
|---|---|---|---|---|---|---|
| 199 pm | | 183 pm | | 181 pm | | 176 pm |
| (weak metallic bond) | | | | | | |

**5. Ans. (2)**

Generally interstitial compounds are chemically inert.

**6. Ans. (2)**

Since Zn is not a transition element so among given transition elements Cu, V, Fe the element of 3d-series having lowest atomisation energy is Cu due to its stable $3d^{10}\ 4s^1$ configuration.

**7. Ans. (4)**

Actinides show larger range of oxidation states than lanthanides because of comparable energy levels of 4f, 5d and 6s and Np and Pu both show oxidation State ranging from +3 to +7

Np → +3, + 4, + 5 , + 6, +7

Pu → + 3, + 4, + 5, + 6, + 7

**8. Ans. (2)**

$_{58}Ce \rightarrow {}_{54}[Xe]\ 4f^1\ \ 5d^1\ \ 6S^2$

$_{58}Ce^{3\oplus} \rightarrow {}_{54}[Xe]\ 4f^1\ \ 5d^0\ \ 6S^0$

$_{63}Eu \rightarrow {}_{54}[Xe]\ 4f^7\ \ 5d^0\ \ 6S^2$

$_{63}Eu^{2\oplus} \rightarrow {}_{54}[Xe]\ 4f^7\ \ 5d^0\ \ 6S^0$

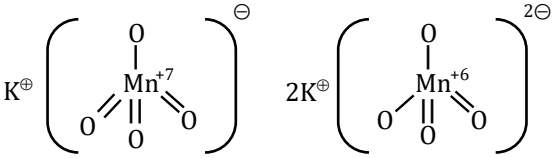
**9. Ans. (1)**

Alloys of lanthanides with Fe are called Misch metal, which consists of a lanthanoid metal (~95%) and iron (~5%) and traces of S, C, Ca and Al which are used to make gas lighters.

**10. Ans. (1)**

$$2KMnO_4 \xrightarrow{573K} K_2MnO_4 + MnO_2 + O_2$$

Potassium permanganate — Potassium manganate



$3d^0\ 4s^0$
Tetrahedral unit
0 unpaired e–
⇒ diamagnetic



$3d^1\ 4s^0$
Tetrahedral unit
1 unpaired e⁻
⇒ paramagnetic

Statement-I is correct.
Statement-II is incorrect.

**11. Ans. (4)**

$E^0_{Mn^{3\oplus}/Mn^{2\oplus}} = +1.57$

$E^0_{Fe^{3\oplus}/Fe^{2\oplus}} = +0.77$

$E^0_{Co^{3\oplus}/Co^{2\oplus}} = +1.97$

$E^0_{Cr^{3\oplus}/Cr^{2\oplus}} = -0.41V$

$Cr^{3\oplus} \Rightarrow 3d^3\ 4s^0$

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

$= \sqrt{15}\,B.M \simeq 4\ B.M$

**12. Ans. (1)**

In acidic medium $KMnO_4$ acts as good oxidising agent and on reaction with $H_2O_2$ in acidic medium it reduces to $Mn^{2\oplus}$ and oxidises $H_2O_2$ to $O_2$

$$H_2O_2 + \overset{+7}{Mn}O_4^{\ominus} \xrightarrow{6H^{\oplus}} \overset{+2}{Mn}^{2\oplus} + \overset{+4}{O}_2 + 4H_2O$$

**13. Ans. (5)**

$E^0_{M^{3\oplus}/M^{2\oplus}}$ values are negative for Ti, V and Cr so their $M^{2\oplus}$ oxi. states are less stable than $M^{3\oplus}$ oxi. states but $Co^{3\oplus}$ is more stable due to positive value of $E^0_{M^{3\oplus}/M^{2\oplus}}$ for Co So,

$Co^{3\oplus}$ can not liberate $H_2$ by reaction with dilute mineral acid solution ($H^{\oplus}$) by reducing $H^{\oplus}$ ion.

$Co^{3\oplus}$ has $d^6$ configuration, So, Number of unpaired electrons = 4

Spin only magnetite moment $\mu = \sqrt{4\times6} = 4.92$ B.M. $\approx 5$ B.M.

**14. Ans. (4)**

(A) Sm can show both +2 and +3 oxidation state so $Sm^{2\oplus}$ can act as reducing agent

(B) Ce shows common oxi. state in $Ce^{3\oplus}$ but it can also show less stable +2 and +4 oxi. States. $Ce^{2\oplus}$ changes to $Ce^{3\oplus}$ and acts as reducing agent.

(C) & (D) $Ce^{4\oplus}$ and $Tb^{4\oplus}$ act as oxidising agent because $Ce^{4\oplus}$ and $Tb^{4\oplus}$ both are having noble gas config. and half-filled electronic configuration respectively but still their $Ce^{3\oplus}$ and $Tb^{3\oplus}$ are most stable oxi. state.

**15. Ans. (2)**

$$14H^{\oplus} + 6e^{\ominus} + \underset{+6}{Cr_2}O_7^{2\ominus} \longrightarrow 2\underset{+3}{Cr}^{3\oplus} + 7H_2O$$

**16. Ans. (3)**

Blue green colour is due to formation of $Cu(BO_2)_2$

$CuSO_4 \xrightarrow{\Delta} CuO + SO_3$

$CuO + B_2O_3 \rightarrow Cu\,(BO_2)_2$

**17. Ans. (2)**

(i), (ii) and (iv) correct.

Manganese exhibits +7 oxidation state in its oxide.

($Mn_2O_7$)

Ru & Os from $RuO_4$ & $OsO_4$ oxide in +8 oxidation state

Cr in +6 oxidation act is oxidizing.

Sc does not show +4 oxidation state.

**18.** **Ans. (4)**

A solution of $CrO_5$ in amyl alcohol has a blue colour. So, option (4) is correct.

**19.** **Ans. (3)**

$$Cr_2O_7^{2\ominus} + SO_3^{2\ominus} \xrightarrow{H^{\oplus}} \underset{\text{Green}}{Cr^{3\oplus}} + SO_4^{2\ominus}$$

**20.** **Ans. (1)**

With increase in % of oxygen acidic nature of oxide of an element increase and basic nature decreases

## EXERCISE - JEE (Advanced) PYQ

**1.** **Ans. (A,B,C)**

(A) $Cr^{2\oplus} \xrightarrow[-e^{\ominus}]{} Cr^{3\oplus}$ $\qquad E^0_{Cr^{3\oplus}/Cr^{2\oplus}} = -0.41$

(B) $Mn^{3\oplus} \xrightarrow{+e^{\ominus}} Mn^{2\oplus}\ (d^5)X$ $\qquad E^0_{Mn^{3\oplus}/Mn^{2\oplus}} = +1.57$

(C) $Cr \rightarrow [Ar]3\,d^5 4S^1 \xrightarrow[-2e^{\ominus}]{} Cr^{2\oplus}[Ar]3d^4 4S^0$

$Mn \rightarrow [Ar]3\,d^5 4S^2 \xrightarrow[-3e^{\ominus}]{} Mn^{3\oplus}[Ar]3d^4 4S^0$

(D) $\underset{3d^4}{Cr^{2\oplus}} \xrightarrow[-e^{\ominus}]{} \underset{3d^3}{Cr^{3\oplus}}$

**2.** **Ans. (B,C,D)**

$$MnO_2 + 2KOH + \frac{1}{2}O_2 \xrightarrow{\Delta} \underset{(W)}{K_2MnO_4} + H_2O$$

$$[(W) = K_2MnO_{4(aq)} \rightleftharpoons 2K^{\oplus}_{(aq)} + \underset{(Y)}{MnO^{2\ominus}_{4(aq)}}]$$

$$K_2MnO_4 + H_2O \xrightarrow[\text{Redox}]{\text{Electrolytic}} H_2 + KOH + \underset{(X)}{KMnO_4}$$

(W)

$$[\text{anion of X} = \underset{(Z)}{MnO_4^{\ominus}}]$$

$$[\because \underset{(Y)}{MnO_4^{2\ominus}} \xrightarrow[\text{Oxidation}]{\text{Electrolytic}} \underset{(Z)}{MnO_4^{\ominus}} + e^{\ominus}]$$

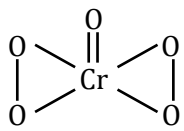
$\because$ In acidic solution; Y undergoes disproportionation reaction

$$3\underset{(Y)}{MnO^{2\ominus}_{4(aq)}} + 4H^{\oplus} \rightarrow 2\underset{(Z)}{MnO_4^{\ominus}} + MnO_2 + 2H_2O$$

**3.** **Ans. (4)**

$$K_2CrO_4 + H_2O_2 \xrightarrow[\substack{\text{Amyl alcohol}\\ \text{1-pentanol}\\ (C_5H_{12}O)}]{\text{(In acidic medium)}} \underset{\substack{(X)\\ \text{(Blue liquid)}}}{CrO_5}$$

Here the structure of $CrO_5$ is :-




Here, single bonded O-atoms with Cr is = 04

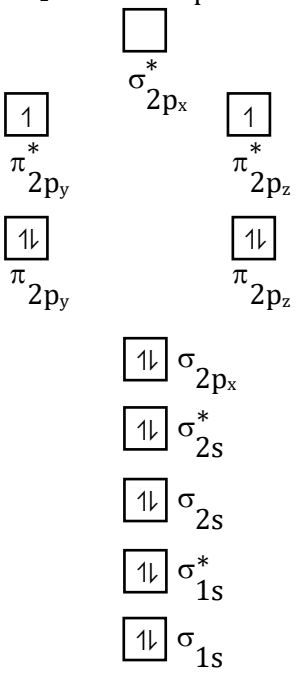
**4.** **Ans. (6)**

$AgNO_3 \rightarrow 2Ag + 2NO_2 + ½O_2$

– Both $NO_2$ & $O_2$ are paramagnetic

– $NO_2$ is odd electron molecule with one unpaired electron

–$O_2$ has two unpaired electrons




Total number of antibonding electrons = 6

## JEE (Main) Practice Paper

### SECTION–A

**1.** **Ans. (1)**

Transition metals have metal defects in their crystal lattice and in these defects or voids or interstitial spaces small atoms dive B, C, N, H etc. get trapped and form interstitial compounds.

**2.** **Ans. (4)**

Along the period moving from left to right acidic character of oxides increases because EN of the central atom increases.

$$\text{Basic character of oxides} \propto \frac{1}{\text{EN of Element}} \propto \frac{1}{Z_{\text{eff}} \text{ of Element}}$$

**3.** **Ans. (2)**

Metallic bond strength $\propto$ No. of unpaired electrons.

Due to increase in unpaired electrons from Sc to Cr metallic bond transom increases but in Mn number of unpaired electrons are 5 but due to its exceptional crystal structure strength of metallic bond is very less.

**4.** **Ans. (1)**

Transition elements ions impart colour due to d-d transition of d-orbital electron. Since there is no unpaired electrons in d-orbital of $Sc^{3\oplus}$ that's why it does not show any colour.

**5.** **Ans. (1)**

In neutral or slight alkaline medium $MnO_4^{\ominus}$ oxidised $I^{\ominus}$ into $IO_3^{\ominus}$

$$2MnO_4^{\ominus} + H_2O + I^{\ominus} \rightarrow 2MnO_2 + 2OH^{\ominus} + IO_3^{\ominus}$$

**6. Ans. (4)**

$$\underset{\text{Orange}}{Cr_2O_7^{2\ominus}} \underset{H^{\oplus}}{\overset{OH^{\ominus}}{\rightleftharpoons}} \underset{\text{Yellow}}{CrO_4^{2\ominus}}$$

$$K_2Cr_2O_7 + 4H_2SO_4 + 3H_2S \rightarrow K_2SO_4 + \underset{(\text{green colour})}{Cr_2(SO_4)_3} + 7H_2O + \underset{(\text{Pale yellow})}{3S}$$

$K_2Cr_2O_7$ generally preferred over $Na_2Cr_2O_7$ in volumetric analysis (titration) because $Na_2Cr_2O_7$ is hygroscopic & reacts with $CO_2$.

**7. Ans. (1)**

$Cu^{2\oplus}$ → Strong oxidising agent
$I^{\ominus}$ → Strong reducing agent
} so both will not exist together.

**8. Ans. (2)**

$$CuSO_4 + \text{dil } H_2SO_4 \rightarrow \underset{\substack{\text{(Blue colour)}\\ \text{(Blue vitriol)}}}{CuSO_4.5H_2O}$$

or

$$[Cu(H_2O)_4].H_2O(SO_4) \Rightarrow [Cu(H_2O_4)]^{2\oplus} = \text{'X'}$$

$$2CuSO_4 + 4KI \rightarrow \underset{(Y)}{Cu_2I_2\downarrow} + I_2 + 2K_2SO_4$$

**9. Ans. (3)**

1. $MnO_4^{2\ominus}$ ion is stable in high alkali medium or high pH and on decreasing pH it disproportionate in $MnO_4^{\ominus}$ and $MnO_2$
2. In Acidic medium, $MnO_4^{\ominus}$ reduced to $Mn^{2\oplus}$ and in neutral or slight alkali medium it reduced to $Mn^{4\oplus}$ that's why it is a good oxidising agent in acidic medium,
3. $KMnO_4$ can acts as oxidising agent in alkaline medium and form $Mn^{4\oplus}$.
   $Mn^{7\oplus} + 3e^{\ominus} \xrightarrow[\text{alkaline medium}]{\text{In}} Mn^{4\oplus}$
4. $MnO_2 \xrightarrow[O_2+KOH]{\text{Fusion}} MnO_4^{2\ominus} \xrightarrow[\text{oxidation}]{\text{electrolytic}} MnO_4^{\ominus}$

**10. Ans. (2)**

Ziegler – Natta catalyst → $TiCl_4 + (C_2H_5)_5Al$
$TiCl_4$ and $(C_2H_5)_3Al$ are connected by Cl bridges
Al – $(Et)_3$ bond causes destabilisation in Ti –alkyl bond (trans effect)

Ti –alkyl bond $\Rightarrow Ti^{4\oplus} \rightarrow Ti^{3\oplus}$

$TiCl_3$ is active species in the Ziegler-Natta catalyst in the production of polythene.

**11. Ans. (1)**

In acidic medium $KMnO_4$ reduced to $Mn^{2\oplus}$ and oxidises oxalic acid to $CO_2$ and $Mn^{2\oplus}$ acts as auto catalyst in further reaction and formation of $CO_2$ becomes fast.

$$2MnO_4^{\ominus} + 5C_2O_4^{2\ominus} + 16H^{\oplus} \xrightarrow{\Delta} 2Mn^{2\oplus} + 10CO_2 + 8H_2O$$

In this reaction, $Mn^{2\oplus}$ acts as auto-catalyst.

**12. Ans. (1)**

The chromates and dichromats are inter-convertible in aqueous solution depends upon pH of the solution.

$$Cr_2O_7^{2\ominus} \underset{H^{\oplus}}{\overset{OH^{\ominus}}{\rightleftharpoons}} CrO_4^{2\ominus}$$

**13. Ans. (1)**

Transition metals show Catalytic activity due to their ability to exist in variable oxidation states, they bind reactant molecules on their surface that reduces interaction among reactant molecules and that leads to speed up the reaction.

**14. Ans. (2)**

When $K_2Cr_2O_7$ is reacted with $H_2SO_4$ it gives $CrO_3$ which reacts with HCl obtained in the Solution by reaction of NaCl and $H_2SO_4$

$K_2Cr_2O_7 + H_2SO_4 \longrightarrow CrO_3 + H_2O$

$NaCl + H_2SO_4 \longrightarrow HCl + NaHSO_4$

$CrO_3 + 2HCl \rightarrow CrO_2Cl_2 + H_2O$

Hybridisation of $CrO_2Cl_2 \Rightarrow d^3S$

Shape $\Rightarrow$ tetrahedral

**15. Ans. (4)**

(I) Basic nature of hydroxide $\propto \frac{1}{EN} \propto \frac{1}{Zeff}$

(II) $Zr^{4\oplus}$ & $Hf^{4\oplus}$ same size due to lanthanide contraction

(III) $Ce^{4\oplus} + \overset{\ominus}{e} \rightarrow Ce^{3\oplus}$ ($Ce^{3\oplus}$ is stable so it can act as oxidising agent)

**16. Ans. (4)**

All actinides are radioactive in nature while Pm is the only lanthanide which is radioactive Synthetic substance.

Nucleus of actinides are larger as compare to lanthanide. In order to become more stable, the nucleus of an actinide element undergoes radioactive decay.

**17. Ans. (4)**

$Y^{3\oplus}$

^

$La^{3\oplus} > E_4^{3\oplus} > L_4^{3\oplus}$

Ionic radii of $Y^{3\oplus}$ is smallest among given 4 ions because

Ionic radius $\propto$ no. of shell

$Y^{3\oplus} < Lu^{3\oplus}$, $Eu^{3\oplus}$ and $La^{3\oplus}$

$Lu^{3\oplus}$, $E_4^{3\oplus}$ and $La^{3\oplus}$ are isoelectronic so ionic radii order will be :

Ionic radius $\propto \frac{1}{Zeff}$

$Lu^{3\oplus} < Eu^{3\oplus} < La^{3\oplus}$

So, the final order of ionic radius will be : $Y^{3\oplus} < Lu^{3\oplus} < Eu^{3\oplus} < La^{3\oplus}$

**18. Ans. (3)**

$_{58}Ce \longrightarrow [Xe]\, 4f^1 5d^1 6s^2$

$_{58}Ce^{4\oplus} \longrightarrow [Xe]\, 4f^0 5d^0 6s^0$

$Ce^{4\oplus} \rightarrow$ extra stability due to inert gas electronic configuration, so it is known in solution.

**19. Ans. (2)**

Lanthanide contraction is caused due to the imperfect shielding on outer electrons by 4f electrons from the nuclear charge.

**20. Ans. (2)**

Basic nature of hydroxide $\propto \frac{1}{\text{EN of element}} \propto \frac{1}{\text{Zeff}}$

In lanthanide series due to lanthanide contraction size decreases & zeff increases, and EN also increases so basicity of oxides and hydroxides decreases.

**SECTION-B**

**1. Ans. (3)**

| Fe | Ni | Cu | Zn | Cd | Ag | Hg | Au |
|---|---|---|---|---|---|---|---|
| +2 | +2 | +1 | +2 | +2 | +1 | +1 | +1 |
| +3 | +3 | +2 | | | | +2 | +3 |
| +4 | +4 | | | | | | |
| +6 | | | | | | | |

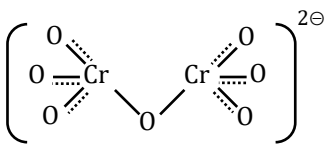
**2. Ans. (8)**

$K_2Cr_2O_7 + 8H^{\oplus} + 3H_2S \rightarrow 2Cr^{3\oplus} + 7H_2O + 3S$ [Cr +6 to +3 change $\rightarrow$ 3]

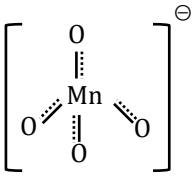
$MnO_4^{\ominus} + 5C_2O_4^{2\ominus} + 16H^{\oplus} \rightarrow 2Mn^{2\oplus} + 8H_2O + 10CO_2$ [Mn +7 to +2 change $\rightarrow$ 5]

X = 3 and Y = 5

**3. Ans. (10)**



Identical Cr-O bonds due to resonance



X = 6

Y = 4

X + Y = 6 + 4 = 10

**4. Ans. (0)**

When $H_2O_2$ reacts with acidified $Cr_2O_7^{2\ominus}$ then deep blue coloured solution is obtained due to formation of $CrO_5$ (Chromium peroxide) that fades away and $CrO_5$ decomposed to $Cr^{3\oplus}$ and $O_{2(g)}$ in aq. Sol. readily and solution becomes green due to $C_2O_3$.

$\overset{+6}{Cr}_2O_7^{2\ominus} + 4H_2O_2 + 2H^{\oplus} \rightarrow 2\overset{+6}{Cr}O_5 + 5H_2O$

**5. Ans. (3)**

In actinide series, all elements after Uranium are synthetic element and all actinides are radioactive elements.

Natural elements among actinides :

Th $\rightarrow$ Thorium

Pa $\rightarrow$ Protactinium

U $\rightarrow$ Uranium

**6. Ans. (6)**

In lanthanide series only Pm (promethium) is radioactive element while all actinide elements are radioactive elements.

lanthanide $\Rightarrow$ Pm (1)

Actinide $\Rightarrow$ all (14)

15 elements are radioactive elements among lanthanides and actinides.

**7.** **Ans. (3)**

| Ion | Configuration | Unpaired Electron |
|---|---|---|
| $Tb^{2\oplus}$ | $4f^9$ | 5 |
| $Ce^{4\oplus}$ | [Xe] | 0 |
| $Yb^{2\oplus}$ | $4f^{14}$ | 0 |
| $Lu^{3\oplus}$ | $4f^{14}$ | 0 |
| $Pr^{2\oplus}$ | $4f^3$ | 3 |
| $Nd^{2\oplus}$ | $4f^3$ | 4 |
| $Pm^{2\oplus}$ | $4f^5$ | 5 |
| $Sm^{2\oplus}$ | $4f^6$ | 6 |
| $Gd^{3\oplus}$ | $4f^7$ | 7 |

$Ce^{4\oplus}$, $Yb^{2\oplus}$, $Lu^{3\oplus}$ are diamagnetic due to absence of unpaired electron

**8.** **Ans. (3)**

Density, Hardness, Melting point

**9.** **Ans. (2)**

In aqueous solution $d^0$ and $d^{10}$ configuration do not produce colour while $d^1$ to $d^9$ show various colours.

| **Ions** | | **Colour in aq. Sol.** |
|---|---|---|
| $Ti^{3\oplus}$ | $\rightarrow$ | Purple |
| $V^{4\oplus}$ | $\rightarrow$ | Blue |
| $Fe^{3\oplus}$ | $\rightarrow$ | Yellow |
| $Co^{2\oplus}$ | $\rightarrow$ | Pink |
| $Ni^{2\oplus}$ | $\rightarrow$ | Green |
| $Cu^{2\oplus}$ | $\rightarrow$ | Blue |

**10.** **Ans. (3)**

I. $BaCl_2 + \overset{+6}{Na_2CrO_4} \xrightarrow{CH_3COOH} \overset{+6}{BaCrO_4}\downarrow + 2NaCl$

(yellow sol.) (yellow ppt)

(Non redox reaction

II. $\overset{+6}{K_2Cr_2O_7} + 2NaOH \longrightarrow \overset{+6}{Na_2CrO_4} + \overset{+6}{K_2CrO_4} + H_2O$

(Orange sol.) (yellow sol.) (yellow sol.)

(Non redox reaction

III. $Cr_2O_7^{2\ominus} + NO_3^{\ominus} \xrightarrow{H^{\oplus}}$ No reaction

IV. $\overset{+6}{2Cr_2O_7^{2\ominus}} + \overset{-2}{3C_2H_5OH} + 16H^{\oplus} \downarrow$

$\overset{-2}{3CH_3}\overset{+2}{COOH} + 4Cr^{3\oplus} + 11H_2O$

(Redox reaction)

## JEE (Advanced) Practice Paper

**1. Ans. (B)**

$MnO_4^{\ominus} + e^{\ominus} \longrightarrow MnO_4^{2\ominus}$

$MnO_4^{\ominus} + 8H^{\oplus} + 5e^{\ominus} \rightarrow Mn^{2\oplus} + 4H_2O$

$MnO_4^{\ominus} + 4H^{\oplus} + 3e^{\ominus} \rightarrow MnO_2 + 2H_2O$

**2. Ans. (A)**

(A) Molybdenum is used in X-rays tube.

(B) Ta is used in the mono facture of electronic components, mainly capacitors.

(C) Tc is used in the medical diagnosis.

(D) Pm is used in atomic batteries, missiles, and pacemakers.

**3. Ans. (C)**

Transition metals have ability to adopt multiple oxidation state and to form complex and they introduced an entirely new reaction mechanism with a lower activation energy

**4. Ans. (A)**

(A) $_{89}Ac \rightarrow [Rn]\ 6d^1\ 7s^2$

$_{89}Ac^{3\oplus} \rightarrow {}_{86}[Rn]\ 6d^0\ 7s^0$

Ac looses $3e^{\ominus}$ to achieve inert gas electronic configuration because it has too few electrons to loose.

(B) Pa $\rightarrow$ +3, +4, +5

(C) U $\rightarrow$ +3, +4, +5, +6

(D) Th $\rightarrow$ +4

**5. Ans. (D)**

Over all decrease in atomic and ionic radii from La to Lu is shown by lanthanide due to lanthanide contraction.

**6. Ans. (A,C,D)**

(A) & (C) in 3d series moving from left to right value of $E^0_{M^{3\oplus}/M^{2\oplus}}$ becomes positive so, stability of +2 oxidation state increases across the period and stability of +3 decreases across the period

(B) $\underset{\text{Size decrease}}{\overset{\text{Sc, Ti, V, Cr, Mn}}{\longrightarrow}}$ $\underset{\text{Remains almost same}}{\overset{\text{Fe, Co, Ni}}{\longrightarrow}}$ $\underset{\text{Increases}}{\overset{\text{Cu, Zn}}{\longrightarrow}}$

(D) Ni, Fe, Cr may show zero oxidation state in some of their compounds like $[Ni(CO)_4]$ $[Fe(CO)_5]$ $[Cr(CO)_6]$

**7. Ans. (A,B,D)**

(A) In general, $d^1$ to $d^9$ electronic configurations are coloured

(B) Zinc has lowest melting point because it doesn't have unpaired electron.

(C) d-block elements show variable oxidation state but it is not necessary that they differ by two units like $Mn^{7\oplus}$ and $Mn^{6\oplus}$

(D) d-block metals easily form complexes due to the comparatively smaller sizes of the metal ions, their high ionic charges and the availability of d orbitals for bond formation.

**8. Ans. (A,B,C)**

$Al_2O_3$, SnO, ZnO $\rightarrow$ Amphoteric oxide

$Fe_2O_3 \rightarrow$ Basic oxide

**9. Ans. (A,B,C)**

(A) Atomic radii $\propto$ no of shell $\propto \frac{1}{\text{zeff}}$

(B) $Sm^{3\oplus} \Rightarrow$ [Xe] $4f^5$ (unpaired $e^{\ominus}$ present)

(C) Among all lanthanides Pm is the only radioactive substance

(D) Most common oxidation states shown by cerium are +3, +4.

**10. Ans. (A)**

$Cr_2O_3 \rightarrow$ Amphoteric

$CrO_3 \rightarrow$ Acidic

$Fe_3O_4 \rightarrow$ Mix oxide ($Fe_2O_3$ + FeO)

$N_2O \rightarrow$ Neutral oxide

**11 Ans. (C)**

(P) $Ni^{2\oplus}$ - $d^8$ -green – paramagnetic, $\mu$ = 2.84

(Q) $Cr^{2\oplus}$ - $d^4$ -blue – paramagnetic, $\mu$ = 4.96

$Cr^{2\oplus} \rightarrow 3d^4 \rightarrow$ d – d transition because in aq. medium it exists as. $[Cr(H_2O)_6]^{2\oplus}$

(R) $V^{2\oplus}$ - $d^3$ - violet – paramagnetic, $\mu$ = 3.92

$V^{2\oplus} \rightarrow d^3 \rightarrow t_{2g}^3 e_g^0$

(S) $Ti^{4\oplus}$ - $d^0$ -colourless – diamagnetic, $\mu$ = 0

**12. Ans. (A)**

(A) $TiCl_4 + (C_2H_5)_3$ Al used as the Ziegler – Natta catalyst in polymerisation of Ethelene of styrene

(B) $PdCl_2$ is used in Wacker process for converting alkenes into aldehydes and ketones.

(C) $PtO_2$. $H_2O$ is used as Adam's catalyst in hydrogenation of alkynes and nitrates.

(D) Cu is used in preparation of $(CH_3)_2SiCl_2$ in powdered form with Si.

**13. Ans. (A)**

(1) $2\,Ln + 6H^{\oplus} \rightarrow 2Ln^{3\oplus} + 3H_2$

Lanthanides get oxidised to $Ln^{3\oplus}$ and liberate $H_2$ when reacting with acids.

(2) $LnC_2 \rightarrow Ln^{2\oplus}C_2^{2\ominus} \xrightarrow{H_2O} Ln(OH)_3 + C_2H_2$

$LnC_2$ produces $Ln(OH)_3$ and ethylene gas upon hydrolysis

(3) $2\,Ln + 3H_2O \rightarrow 2Ln(OH)_3 + \frac{3}{2}H_2$

Ln upon hydrolysis produces $Ln(OH)_3$

(4) $4Ln + 3O_2 \rightarrow 2Ln_2O_3$

Ln on burning with $O_2$ produces $Ln_2O_3$.

**14. Ans. (B)**

$MnO_2 + KClO_3 + KOH$ (A)

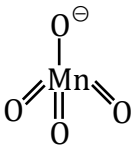
$\downarrow$

$K_2MnO_4$ (Green) (B)

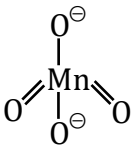
$\downarrow H^{\oplus}$

$KMnO_4$ (Purple) (C)

**15. Ans. (D)**



[C]



[B]

$Mn^{7\oplus} \rightarrow [Ar]3d^0 4s^0$ $Mn^{6\oplus} \rightarrow [Ar]3d^1 4s^0$

O unpaired e⁻ 1 unpaired e⁻

Diamagnetic paramagnetic

$2MnO_4^{\ominus} + H_2SO_4 \rightarrow Mn_2O_7 + K_2SO_4 + H_2O$

(Oily dark green)

**16. Ans. (B)**

$_{64}Gd$ : $[Xe]\ 4f^7 5d^1 6s^2$

**17. Ans. (A)**

Basic nature of hydroxide $\alpha \frac{1}{EN} \alpha \frac{1}{Zeff}$

**18. Ans. (11.00)**

$3K_2MnO_4 + 2H_2O + 4CO_2 \rightarrow 2\overset{+7}{K}\overset{+7}{Mn}O_4 + \overset{+4}{Mn}O_2 + 4KHCO_3$

$n_1 = 7, n_2 = 4$

$n_1 + n_2 = 11$

**19. Ans. (6.00)**

Mohr's salt

$FeSO_4.(NH_4)_2SO_4.6H_2O$

$6\,Fe^{2\oplus} + Cr_2O_7^{2\ominus} + 14\,H^{\oplus} \rightarrow 2Cr^{3\oplus} + 7H_2O + 6Fe^{3\oplus}$

**20. Ans. (95.00)**

95% lanthanide metal + 5% Iron. and traces of Sulphur, Carbon, Calcium and Aluminium.