Multiple Choice Questions [1 mark]

Choose and write the correct option(s) in the following questions.

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

(*a*) 25 (*b*) 26 (*c*) 27 (*d*) 24

2. 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

[*NCERT Exemplar*]

(*a*) Fe (*b*) Ni (*c*) Co (*d*) Cu

3. Which of the following statements is not correct? [*NCERT Exemplar*]

(*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.

4. Which of the following is amphoteric oxide?

Mn_2O_7, CrO_3, Cr_2O_3, CrO, V_2O_5, V_2O_4 [*NCERT Exemplar*]

(*a*) V_2O_5, Cr_2O_3 (*b*) Mn_2O_7, CrO_3

(*c*) CrO, V_2O_5 (*d*) V_2O_5, V_2O_4

5. Which one of the following does not correctly represent the correct order of the property indicated against it ?

(*a*) Ti < V < Cr < Mn, increasing number of oxidation states

(*b*) Ti < V < Mn < Cr, increasing second ionisation enthalpy

(*c*) Ti < V < Cr < Mn, increasing melting point

(*d*) $Ti^{3+} < V^{3+} < Cr^{3+} < Mn^{3+}$, increasing magnetic moment

6. The magnetic moment is associated with its spin angular momentum and orbital angular momentum. Spin only magnetic moment value of Cr^{3+} ion is _____. [*NCERT Exemplar*]

(*a*) 2.87 B.M. (*b*) 3.87 B.M. (*c*) 3.47 B.M. (*d*) 3.57 B.M.

7. Transition elements show magnetic moment due to spin and orbital motion of electrons. Which of the following metallic ions have almost same spin only magnetic moment? [*NCERT Exemplar*]

(*a*) Co^{2+} (*b*) Cr^{2+} (*c*) Mn^{2+} (*d*) Cr^{3+}

8. The electronic configuration of Cu(II) is $3d^9$ whereas that of Cu(I) is $3d^{10}$. Which of he following is correct? [*NCERT Exemplar*]

(*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

9. Generally transition elements form coloured salts due to the presence of unpaired electrons. Which of the following compounds will be coloured in solid state? [*NCERT Exemplar*]

(*a*) Ag_2SO_4 (*b*) CuF_2 (*c*) ZnF_2 (*d*) Cu_2Cl_2

10. Which of the following statement about transition element is not correct?

(*a*) They show variable oxidation states.

(*b*) They exhibit diamagnetic and paramagnetic properties.

(*c*) All ions are coloured.

(*d*) They exhibit catalytic property.

11. **On addition of small amount of $KMnO_4$ to concentrated H_2SO_4, a green oily compound is obtained which is highly explosive in nature. Identify the compound from the following.** [*NCERT Exemplar*]

(*a*) Mn_2O_7 (*b*) MnO_2 (*c*) $MnSO_4$ (*d*) Mn_2O_3

12. **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?** [*NCERT Exemplar*]

(*a*) $KMnO_4$ (*b*) $Ce(SO_4)_2$ (*c*) $TiCl_4$ (*d*) Cu_2Cl_2

13. **When $KMnO_4$ solution is added to oxalic acid solution, the decolourisation is slow in the beginning but becomes instantaneous after some time because** [*NCERT Exemplar*]

(*a*) CO_2 is formed as the product. (*b*) Reaction is exothermic.

(*c*) MnO_4^- catalyses the reaction. (*d*) Mn^{2+} acts as autocatalyst.

14. **Which of the following reactions are disproportionation reactions?** [*NCERT Exemplar*]

(*i*) $Cu^+ \longrightarrow Cu^{2+} + Cu$

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

(*iii*) $2KMnO_4 \longrightarrow K_2MnO_4 + MnO_2 + O_2$

(*iv*) $2MnO_4^- + 3Mn^{2+} + 2H_2O \longrightarrow 5MnO_2 + 4H^+$

(*a*) (*i*), (*ii*) (*b*) (*i*), (*ii*), (*iii*) (*c*) (*ii*), (*iii*), (*iv*) (*d*) (*i*), (*iv*)

15. **$KMnO_4$ acts an oxidising agent in acidic medium. The number of moles of $KMnO_4$ that will be needed to react with one mole of sulphide ions in acidic solution is** [*NCERT Exemplar*]

(*a*) $\frac{2}{5}$ (*b*) $\frac{3}{5}$ (*c*) $\frac{4}{5}$ (*d*) $\frac{1}{5}$

16. **$KMnO_4$ acts as an oxidising agent in alkaline medium. When alkaline $KMnO_4$ is treated with KI, iodide ion is oxidised to _____.** [*NCERT Exemplar*]

(*a*) I_2 (*b*) IO^- (*c*) IO_3^- (*d*) IO_4^-

17. **Which of the following oxidation state is common for all lanthanoids?** [*NCERT Exemplar*]

(*a*) +2 (*b*) +3 (*c*) +4 (*d*) +5

18. **Gadolinium belongs to 4*f* series. It's atomic number is 64. Which of the following is the correct electronic configuration of gadolinium?** [*NCERT Exemplar*]

(*a*) [Xe] $4f^7\,5d^1\,6s^2$ (*b*) [Xe] $4f^6\,5d^2\,6s^2$

(*c*) [Xe] $4f^8\,6d^2$ (*d*) [Xe] $4f^9\,5s^1$

19. **Identify the incorrect statement among the following:**

(*a*) Lanthanoid contraction is the accumulation of successive shrinkages.

(*b*) There is a decrease in the radii of the atoms or ions as one proceeds from La to Lu.

(*c*) As a result of lanthanoid contraction, the properties of 4*d* series of the transition elements have no similarities with the 5*d* series of elements.

(*d*) Shielding power of 4*f* electrons is quite weak.

20. **Actinoids exhibit greater number of oxidation states than lanthanoids. The main reason being**

(*a*) more energy difference between 5*f* and 6*d* than between 4*f* and 5*f* orbitals

(*b*) 4*f* orbitals are more diffused than the 5*f* orbitals

(*c*) lesser energy difference between 5*f* and 6*d* than between 4*f* and 5*d* orbitals

(*d*) more reactive nature of the actinoids than the lanthanoids.

Answers

1. (*b*)	**2.** (*d*)	**3.** (*a*)	**4.** (*a*)	**5.** (*c*)	**6.** (*b*)	**7.** (*a, d*)	**8.** (*a*)	**9.** (*b*)	**10.** (*c*)
11. (*a*)	**12.** (*a, b*)	**13.** (*d*)	**14.** (*a*)	**15.** (*a*)	**16.** (*c*)	**17.** (*b*)	**18.** (*a*)	**19.** (*c*)	**20.** (*c*)

Assertion-Reason Questions

In the following questions, two statements are given—one labeled Assertion (A) and the other labeled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is correct, but Reason (R) is incorrect statement.

(d) Assertion (A) is incorrect, but Reason (R) is correct statement.

1. Assertion (A) : In transition elements *ns* orbital is filled up first and $(n-1)d$ afterwards, during ionization *ns* electrons are lost prior to $(n-1)d$ electrons.

Reason (R) : The effective nuclear charge felt by $(n-1)d$ electrons is higher as compared to that by *ns* electrons.

2. Assertion (A) : Zn, Cd and Hg cannot be regarded as transition elements.

Reason (R) : These elements do not belong to the *d*-block of the periodic table.

3. Assertion (A) : Transition metals are strong reducing agents.

Reason (R) : Transition metals form numerous alloys with other metals.

4. Assertion (A) : Amongst Cu^{2+} and Cu^{+} ions, the more stable ions is Cu^{2+}.

Reason (R) : For determination of stability of an ion its electrode potential is more important factor than its electronic configuration.

5. Assertion (A) : Transition metals form complexes.

Reason (R) : Transition metals have unpaired electrons.

6. Assertion (A) : A solution of ferric chloride on standing gives a brown precipitate.

Reason (R) : $FeCl_3$ possesses covalent bonds and chlorine bridge structure.

7. Assertion (A) : Members of 4*d* and 5*d* series of transition elements have nearly same atomic radii.

Reason (R) : Atomic and ionic radii for transition elements are smaller than their corresponding *s*-block elements.

8. Assertion (A) : The most common oxidation state exhibited by actinoids is +2.

Reason (R) : All actinoids possess two electrons in 7*s* subshell.

9. Assertion (A) : Ce^{4+} is used as an oxidising agent in volumetric analysis.

Reason (R) : Ce^{4+} has the tendency of attaining +3 oxidation state.

10. Assertion (A) : The degree of complex formation in actinides decreases in the order

$$M^{4+} > MO_2^{2+} > M^{3+} > MO_2^{+}$$

Reason (R) : Actinides form complexes with π-bonding ligands such as alkyl phosphines and thioethers.

Answers

1. (*a*) **2.** (*c*) **3.** (*d*) **4.** (*b*) **5.** (*b*) **6.** (*b*) **7.** (*b*) **8.** (*d*) **9.** (*a*) **10.** (*b*)

Passage-based/Case-based Questions

Read the given passages and answer the questions that follow.

PASSAGE–1

The *d*-block elements are those elements in which the last electron enters the *d*-subshell of the penultimate shell. The general electronic configuration of these elements is $(n-1)\,d^{1-10}\,ns^{1-2}$, where *n* is outermost shell. The *d*-block consisting of groups 3–12 occupies the large middle section of the periodic table. The elements of *d*-block are also

known as transition elements as they possess properties that are transitional between the *s* and *p* block elements. A transition element is defined as an element which has incompletely filled *d*-orbitals in its ground state or any one of its oxidation states. There are four series of transition elements spread between group 3 and 12. First transition series or 3*d*-series: Scandium ($_{21}$Sc) to Zinc ($_{30}$Zn), Second transition series or 4*d*-series: Yttrium ($_{39}$Y) to Cadmium ($_{48}$Cd), Third transition series or 5*d*-series: Lanthanum ($_{57}$La) and Hafnium ($_{72}$Hf) to Mercury ($_{80}$Hg) (Omitting $_{58}$Ce to $_{71}$Lu), Fourth transition series or 6*d*-series: Begins with Actinium ($_{89}$Ac) is still incomplete.

1. In what way is the electronic configuration of transition elements different from that of the non-transition elements?

Ans. Transition elements contain incompletely filled *d*-subshell, *i.e.*, their electronic configuration is $(n-1)\,d^{1-10}\,ns^{1-2}$ whereas non-transition elements have no *d*-subshell or their subshell is completely filled and have ns^{1-2} or $ns^2\,np^{1-6}$ in their outermost shell.

2. Why is zinc not regarded as a transition element? ***[CBSE Guwahati 2015]***

Ans. As zinc atom has completely filled *d*-orbitals ($3d^{10}$) in its ground state as well as in oxidised state, therefore, it is not regarded as a transition element.

3. Why does a transition series contain 10 elements?

Ans. There are five *d*-orbitals in an energy level and each orbital can contain two electrons. As we move from one element to the next, an electron is added and for complete filling of the five *d*-orbitals, 10 electrons are required.

4. Name the element which shows outer electronic configuration $3d^3\,4s^2$.

Ans. Vanadium

5. What are interstitial compounds?

Ans. Interstitial compounds are those in which small atoms occupy the interstitial sites in the crystal lattice.

PASSAGE–2

Potassium permanganate, ($KMnO_4$) is prepared by fusion of pyrolusite, MnO_2 with KOH in the presence of an oxidising agent like KNO_3. This produces the dark green potassium manganate, K_2MnO_4 which disproportionates in a neutral or acidic solution to give purple permanganate ion. Potassium permanganate is an important oxidising agent in acidic, alkaline as well as neutral medium.

1. What is the state of hybridisation of Mn in MnO_4^-?

Ans. sp^3

2. Write an application of potassium permanganate.

Ans. It is used for the estimation of hydrogen peroxide.

3. What are the products formed after heating potassium permanganate?

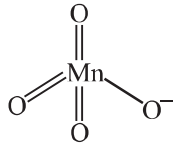
Ans. K_2MnO_4, O_2 and MnO_2 will be formed after heating of potassium permanganate.

4. How many electrons are involved in oxidation by $KMnO_4$ in an acidic medium?

Ans. Five electrons are involved in oxidation by $KMnO_4$ in an acidic medium.

5. Draw the structure of permanganate ion. Is it paramagnetic or diamagnetic?

Ans.



Tetrahedral permanganate ion
(purple)

It is diamagnetic.

Very Short Answer Questions [1 mark]

Q. 1. Copper atom has completely filled *d*-orbitals in its ground state but it is a transition element. Why? ***[CBSE Chennai 2015]***

Ans. Copper exhibits +2 oxidation state wherein it has incompletely filled *d* orbitals ($3d^9\,4s^0$) hence, a transition element.

Q. 2. Give reason:

Zn is soft whereas Cr is hard. **[*CBSE South 2016*]**

Ans. Cr ($3d^5\ 4s^1$) has five unpaired electrons in its *d*-orbitals whereas Zn ($3d^{10}\ 4s^2$) has no unpaired electrons in its *d*-orbitals. As a result of this weak metallic bonds exist in Zn whereas strong metallic bonds exist in Cr. Hence, Zn is soft whereas Cr is hard.

Q. 3. Reactivity of transition elements decreases almost regularly from Sc to Cu. Explain. **[*NCERT Exemplar*]**

Ans. It is due to regular increase in ionisation enthalpy.

Q. 4. Arrange the following in increasing order of acidic character: **[*HOTS*]**

CrO_3, CrO, Cr_2O_3

Ans. $CrO < Cr_2O_3 < CrO_3$. Higher the oxidation state, more will be acidic character.

Q. 5. Why does copper not replace hydrogen from acids? **[*NCERT Exemplar*]**

Ans. Cu shows E^o positive value.

Q. 6. Which divalent metal ion has maximum paramagnetic character among the first transition metals? Why?

Ans. Mn^{2+} has the maximum paramagnetic character because of the maximum number of unpaired electrons, *viz.*, 5.

Q. 7. Although Cr^{3+} and Co^{2+} ions have same number of unpaired electrons but the magnetic moment of Cr^{3+} is 3.87 BM and that of Co^{2+} is 4.87 BM. Why? **[*NCERT Exemplar*] [*HOTS*]**

Ans. Due to symmetrical electronic configuration there is no orbital contribution in Cr^{3+} ion. However, appreciable orbital contribution takes place in Co^{2+} ion.

Q. 8. Out of Cu_2Cl_2 and $CuCl_2$, which is more stable and why? **[*NCERT Exemplar*] [*HOTS*]**

Ans. $CuCl_2$ is more stable than Cu_2Cl_2. The stability of $Cu^{2+}(aq)$ is more than $Cu^{+}(aq)$ due to the much more negative $\Delta_{hyd.}H^o$ of $Cu^{2+}(aq)$ than $Cu^{+}(aq)$.

Q. 9. Zn^{2+} salts are white while Cu^{2+} salts are coloured. Why? **[*CBSE Patna 2015*]**

Ans. Cu^{2+} ($3d^9\ 4s^0$) has one unpaired electron in *d*-subshell which absorbs radiation in visible region resulting in *d-d* transition and hence Cu^{2+} salts are coloured. Zn^{2+} ($3d^{10}\ 4s^0$) has completely filled *d*-orbitals. No radiation is absorbed for *d-d* transition and hence Zn^{2+} salts are colourless.

Q. 10. Write any one use of pyrophoric alloys.

Ans. Pyrophoric alloys emit sparks when struck. Hence, they are used in making flints for lighters.

Short Answer Questions–I [2 marks]

Q. 1. Use the data to answer the following and also justify giving reason: **[*CBSE 2019 (56/4/1)*]**

	Cr	Mn	Fe	Co
$E^o_{M^{2+}/M}$	–0.91	–1.18	–0.44	–0.28
$E^o_{M^{3+}/M^{2+}}$	–0.41	–1.57	–0.77	+1.97

(*i*) Which is a stronger reducing agent in aqueous medium, Cr^{2+} or Fe^{2+} and why?

(*ii*) Which is the most stable ion in +2 oxidation and why?

Ans. (*i*) Cr^{2+}, due to lower standard reduction potential (E^o)/Higher standard oxidation potential.

(*ii*) Mn^{2+}, due to highest negative standard reduction potential.

Q. 2. In the following ions:

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

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

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

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

(*iii*) Which ion is colourless?

(*iv*) Which ion has the highest number of unpaired electrons? **[*CBSE (F) 2017*]**

Ans. (*i*) Cr^{3+} because of half filled t_{2g} level.

(*ii*) Mn^{3+}, as the change from Mn^{3+} to Mn^{2+} results in stable half filled (d^5) configuration.

(*iii*) Ti^{4+}, as Ti^{4+} has empty *d*-orbitals therefore *d-d* transition cannot occur in Ti^{4+}.

(*iv*) Mn^{3+} ($3d^4 4s^0$). It has 4 unpaired electrons.

Q. 3. Give reasons for the following:

(*i*) E° values of Mn, Ni and Zn are more negative than expected.

(*ii*) $[Ti(H_2O)]^{3+}$ is coloured while $[Sc(H_2O)_6]^{3+}$ is colourless. ***[HOTS]***

OR

Ti^{3+} is coloured whereas Sc^{3+} is colourless in aqueous solution. ***[CBSE 2020 (56/5/1)]***

Ans. (*i*) Negative E° values for Mn^{2+} and Zn^{2+} are related to stabilities of half-filled and fully filled configurations, respectively. But for Ni^{2+}, E° value is related to the highest negative enthalpy of hydration.

(*ii*) This is due to *d-d* transition of electron in $[Ti(H_2O)_6]^{3+}$ complex. Ti^{3+} has one electron in *d*-orbital ($3d^1$) which absorbs energy corresponding to blue-green region and jumps from t_{2g} to e_g set of *d*-orbitals ($t^1_{2g}\, e^0_g \longrightarrow t^0_{2g}\, e^1_g$). But Sc^{3+} has no electron in the *d*-orbital.

Q. 4. How would you account for the following:

(*i*) Mn (III) undergoes disproportionation reaction easily.

(*ii*) Co (II) is easily oxidised in the presence of strong ligands. ***[CBSE (F) 2011]***

Ans. (*i*) Mn^{3+} is less stable and changes to Mn^{2+} which is more stable due to half filled *d*-orbital configuration. That is why, Mn^{3+} undergoes disproportionation reaction.

(*ii*) Co (II) has electronic configuration $3d^7\, 4s^0$, *i.e.*, it has three unpaired electrons. In the presence of strong ligands, two unpaired electrons in 3*d*-subshell pair-up and third unpaired electron shifts to higher energy subshell from where it can be easily lost and hence oxidised to Co(III).

Q. 5. When $FeCr_2O_4$ is fused with Na_2CO_3 in the presence of air it gives a yellow solution of compound (A). Compound (A) on acidification gives compound (B). Compound (B) on reaction with KCl forms an orange coloured (C). An acidified solution of compound (C) oxidises Na_2SO_3 to (D). Identify (A), (B), and (D.) ***[CBSE 2019 (56/2/1)]***

Ans. A = $\underset{\text{Sodium chromate}}{Na_2CrO_4}$, B = $\underset{\text{Sodium dichromate}}{Na_2Cr_2O_7}$, C = $\underset{\text{Potassium dichromate}}{K_2Cr_2O_7}$, D = $\underset{\text{Sodium sulphate}}{Na_2SO_4}$

Q. 6. Complete the following chemical reaction equations:

(*i*) $MnO_4^-(aq) + C_2O_4^{2-}(aq) + H^+(aq) \longrightarrow$

(*ii*) $Cr_2O_7^{2-}(aq) + Fe^{2+}(aq) + H^+(aq) \longrightarrow$

Ans. (*i*)
$$[MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O] \times 2$$
$$[C_2O_4^{2-} \longrightarrow 2CO_2 + 2e^-] \times 5$$
$$MnO_4^- + 5C_2O_4^{2-} + 16H^+ \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

(*ii*)
$$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$$
$$Fe^{2+} \longrightarrow Fe^{3+} + e^-] \times 6$$
$$Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \longrightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$$

Q. 7. Complete the following chemical equations:

(*i*) $8MnO_4^- + 3S_2O_3^{2-} + H_2O \longrightarrow$

(*ii*) $Cr_2O_7^{2-} + 3Sn^{2+} + 14H^+ \longrightarrow$ ***[CBSE Delhi 2016]***

Ans. (*i*)
$$8MnO_4^- + 2H_2O + 3e^- \longrightarrow MnO_2 + 4OH^-] \times 8$$
$$S_2O_3^{2-} + 10OH^- \longrightarrow 2SO_4^{2-} + 5H_2O + 8e^-] \times 3$$
$$8MnO_4^- + 3S_2O_3^{2-} + H_2O \longrightarrow 8MnO_2 + 6SO_4^{2-} + 2OH^-$$

(*ii*)
$$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$$
$$Sn^{2+} \longrightarrow Sn^{4+} + 2e^-] \times 3$$
$$Cr_2O_7^{2-} + 3Sn^{2+} + 14H^+ \longrightarrow 2Cr^{3+} + 3Sn^{4+} + 7H_2O$$

Q. 8. Complete and balance the following equations: *[CBSE 2019 (56/5/2)]*

(*i*) $MnO_4^- + I^- + H^+ \longrightarrow$

(*ii*) $Na_2Cr_2O_7 + KCl \longrightarrow$

Ans. (*i*) $2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5I_2$

(*ii*) $Na_2Cr_2O_7 + 2KCl \longrightarrow K_2Cr_2O_7 + 2NaCl$

Q. 9. Transition metals can act as catalysts because these can change their oxidation state. How does Fe(III) catalyse the reaction between iodide and persulphate ions? *[NCERT Exemplar]*

Ans. Reaction between iodide and persulphate ions is:

$$2I^- + S_2O_8^{2-} \xrightarrow{Fe(III)} I_2 + 2SO_4^{2-}$$

Role of Fe(III) ions:

$$2Fe^{3+} + 2I^- \longrightarrow 2Fe^{2+} + I_2$$

$$2Fe^{2+} + S_2O_8^{2-} \longrightarrow 2Fe^{3+} + 2SO_4^{2-}$$

Q. 10. Explain each of the following observations:

(*i*) Mn^{2+} is much more resistant than Fe^{2+} towards oxidation. *[CBSE Delhi 2012]*

(*ii*) Among lanthanoids, Ln(III) compounds are predominant. However, occasionally in solutions or in solid compounds, +2 and +4 ions are also obtained. *[CBSE (AI) 2012]*

Ans. (*i*) $Mn^{3+}(d^4)$ is less stable than Mn^{2+} (d^5, half filled) while Fe^{3+} (d^5, half filled) is more stable than Fe^{2+} (d^4). That is why Mn^{2+} is more resistance than Fe^{2+} towards oxidation.

(*ii*) Lanthanoid metals show +2 and +4 oxidation states to attain extra stable f^0 and f^7 configurations.

Q. 11. Explain each of the following observations:

(*i*) Actinoids exhibit a much larger number of oxidation states than the lanthanoids. *[CBSE 2019 (56/2/1)]*

(*ii*) There is hardly any increase in atomic size with increasing atomic numbers in a series of transition metals. *[CBSE (F) 2012]*

Ans. (*i*) This is due to small energy gap between 5*f*, 6*d* and 7*s* subshells in actinoids.

(*ii*) This is because with increase in atomic number in a series, the increased nuclear charge is partly cancelled by the increased shielding effect of electrons in the *d*-orbitals of penultimate shell.

Short Answer Questions–II [3 marks]

Q. 1.

$E^o_{Mn^{2+}/Mn}$	Cr	Mn	Fe	Co	Ni	Cu
	−0.91	−1.18	−0.44	−0.28	−0.25	+0.34

From the given data of E^o values, answer the following questions:

(*i*) Why is $E^o_{(Cu^{2+}/Cu)}$ value exceptionally positive?

(*ii*) Why is $E^o_{(Mn^{2+}/Mn)}$ value highly negative as compared to other elements?

(*iii*) Which is a stronger reducing agent Cr^{2+} or Fe^{2+} ? Give reason. *[CBSE Patna 2015]* *[HOTS]*

Ans. (*i*) Copper has high enthalpy of atomisation and low enthalpy of hydration. Since the high energy to transform Cu(*s*) to $Cu^{2+}(aq)$ is not balanced by hydration enthalpy, therefore, $E^o_{Cu^{2+}/Cu}$ value is exceptionally positive.

(*ii*) This is due to extra stability of half-filled 3*d*-orbitals of $Mn^{2+}(3d^5)$.

(*iii*) Refer to NCERT Intext Questions, Q. 7.

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

Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn **[*CBSE East 2016*]**

Answer the following:

(*i*) Copper has exceptionally positive $E^{\circ}_{M^{2+}/M}$ value. Why?

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

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

Ans. (*i*) Because the sum of sublimation enthalpy and hydration enthalpy to convert Cu(*s*) to $Cu^{2+}(aq)$ is so high that it is not balanced by its hydration enthalpy.

(*ii*) Cr is strongest reducing agent in +2 oxidation state. Cr^{2+} has configuration $3d^4$. After losing one electron it forms Cr^{3+} which has stable half filled t_{2g} level.

(*iii*) $Zn^{2+}(3d^{10})$ has completely filled *d*-orbitals. As a result of this, *d*-*d* transition cannot occur and hence, Zn^{2+} salts are colourless.

Q. 3. (*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 $\quad Cr^{3+}/Cr^{2+} = -0.4$ V

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

$Fe^{2+}/Fe = -0.4$ V $\quad Fe^{3+}/Fe^{2+} = +0.8$ 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? **[*CBSE Sample Paper 2016*]**

Ans. (*i*) (*a*) Higher the reduction potential of a species, greater is the ease with which it undergo reduction. Among these pairs, Mn^{3+}/Mn^{2+} has largest positive reduction potential. Hence Mn^{3+} can be easily reduced to Mn^{2+} *i.e.*, Mn^{3+} is least stable. Cr^{3+}/Cr^{2+} has a negative E° value, therefore, Cr^{3+} is most stable. Fe^{3+}/Fe^{2+} has a positive value but small. Hence, Fe^{3+} is more stable than Mn^{3+} but less stable than Cr^{3+}.

(*b*) Lower the reduction potential or higher the oxidation potential of a species, greater is the ease with which it undergo oxidation. Among these pairs, Mn^{2+}/Mn has the most negative reduction potential or most positive oxidation potential. Therefore, it will be most easily oxidised. Thus, the decreasing order of their ease of oxidation is Mn > Cr > Fe.

(*ii*) In the complex $K_4[Mn(CN)_6]$, Mn is in +2 oxidation state. Magnetic moment 2.2 BM indicates that it has only one unpaired electron and hence forms inner orbital or low spin octahedral complex. In presence of CN^-, a strong ligand the hybridisation involved is d^2sp^3.

Q. 4. 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*) $E^{\circ}_{M^{2+}/M}$ values for transition metals show irregular variation. **[*CBSE (F) 2017*]**

Ans. (*i*) This is because Eu^{2+} tends to change to Eu^{3+} as +3 is the common oxidation state of lanthanoids.

(*ii*) In alkaline medium, the orange colour of the solution changes to yellow due to conversion of dichromate ($Cr_2O_7^{2-}$) ion to chromate (CrO_4^{2-}) ion.

$$\underset{\text{Orange}}{Cr_2O_7^{2-}} + 2OH^- \rightleftharpoons \underset{\text{Yellow}}{2CrO_4^{2-}} + H_2O$$

(*iii*) The irregularity is due to the irregular variation of ionisation enthalpies ($\Delta_i H + \Delta_i H_2$) and also the sublimation enthalpies which are relatively much less for Mn (240 kJ mol^{-1}) and V (470 kJ mol^{-1}).

Q. 5. Complete the following reactions: [*CBSE 2019 (56/4/1)*]

(*i*) $MnO_2 + KOH + O_2 \longrightarrow$

(*ii*) $I^- + MnO_4^- + H^+ \longrightarrow$

(*iii*) $Cr_2O_7^{2-} + Sn^{2+} + H^+ \longrightarrow$

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

(*ii*) $10I^- + 2MnO_4^- + 16H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5I_2$

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

Q. 6. When a brown compound of manganese (A) is treated with HCl it gives a gas (B). The gas taken in excess, reacts with NH_3 to give an explosive compound (C). Identify compounds A and B. [*NCERT Exemplar*] [*HOTS*]

Ans. A = MnO_2 [Manganese (IV) oxide]

B = Cl_2 (Chlorine)

C = NCl_3 (Nitrogen trichloride)

$$\underset{(A)}{MnO_2} + 4HCl \longrightarrow MnCl_2 + \underset{(B)}{Cl_2\uparrow} + 2H_2O$$

$$NH_3 + \underset{(excess)}{3Cl_2} \longrightarrow \underset{(C)}{NCl_3} + 3HCl$$

Q. 7. A solution of $KMnO_4$ on reduction yields either a colourless solution or a brown precipitate or a green solution depending on pH of the solution. What different stages of the reduction do these represent and how are they carried out? [*NCERT Exemplar*]

Ans. Oxidising behaviour of $KMnO_4$ depends on pH of the solution.

In acidic medium (pH < 7),

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

In alkaline medium (pH > 7),

$$MnO_4^- + e^- \longrightarrow \underset{(Green)}{MnO_4^{2-}}$$

In neutral medium (pH = 7),

$$MnO_4^- + 2H_2O + 3e^- \longrightarrow \underset{(Brown\ precipitate)}{MnO_2} + 2OH^-$$

Q. 8. (*i*) How would you account for the following:

(*a*) Highest fluoride of Mn is MnF_4 whereas the highest oxide is Mn_2O_7.

(*b*) Transition metals and their compounds show catalytic properties. [*CBSE 2020 (56/5/1)*]

(*ii*) Complete the following equation:

$3MnO_4^{2-} + 4H^+ \longrightarrow$ [*CBSE (F) 2015*]

Ans. (*i*) (*a*) As oxygen stabilises manganese more than fluorine by forming multiple bonds.

(*b*) The catalytic activity of transition metals and their compounds is attributed to the following reasons:

- Due to their tendency to show variable oxidation states transition metals form unstable intermediate compounds and provide a new path for the reaction with lower activation energy.
- In some cases, the transition metals provide a suitable large surface area with free valencies on which reactants are adsorbed.

(*ii*) $\underset{\text{Manganate ion}}{3MnO_4^{2-}} + 4H^+ \longrightarrow \underset{\text{Permanganate ion}}{2MnO_4^-} + MnO_2 + 4H_2O$

Q. 9. Explain the following observations:

(*i*) The enthalpies of atomisation of transition metals are quite high.

(*ii*) There is a close similarity in physical and chemical properties of the 4*d* and 5*d* series of the transition elements, much more than expected on the basis of usual family relationship.

(*iii*) The members in the actinoid series exhibit larger number of oxidation states than the corresponding members in the lanthanoid series. ***[NCERT Exemplar]***

Ans. (*i*) This is because transition metals have strong metallic bonds as they have large number of unpaired electrons.

(*ii*) This is because 5*d* and 4*d*-series elements have virtually the same atomic and ionic radii due to lanthanoid contraction. Due to equality in size of Zr and Hf, Nb and Ta, Mo and W, etc., the two elements of each pair have the same properties.

(*iii*) The members in the actinoid series exhibit larger number of oxidation states than the corresponding members in the lanthanoid series due to the fact that the 5*f*, 6*d* and 7*s* levels are of comparable energies.

Q. 10. Account for the following:

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

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

(*iii*) Actinoids show wide range of oxidation states. ***[CBSE (F) 2016]***

Ans. (*i*) Mn has + 7 oxidation state in Mn_2O_7 and + 2 in MnO. In low oxidation state of the metal, some of the valence electrons of the metal atom are not involved in bonding. Hence, it can donate electrons and behave as a base. On the other hand, in higher oxidation state of the metal, valence electrons are involved in bonding and are not available. Instead effective nuclear charge is high and hence it can accept electrons and behave as an acid.

(*ii*) Copper exhibits +2 oxidation state wherein it will have incompletely filled *d*-orbitals ($3d^9$), hence a transition metal.

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

Long Answer Questions [5 marks]

Q. 1. (*i*) The elements of 3*d* transition series are given as:

Sc Ti V Cr Mn Fe Co Ni Cu Zn

Answer the following:

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

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

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

(*ii*) Write the equations involved in the preparation of potassium dichromate from sodium chromate (Na_2CrO_4). ***[CBSE (F) 2016]***

Ans. (*i*) (*a*) Cr, the highest melting point of Cr is attributed to the involvement of greater number of electrons(5) from 3*d* in addition to 4*s* electrons in interatomic metallic bonding.

(*b*) Mn, because the change from Mn^{3+} (d^4) to Mn^{2+} (d^5) results in the half filled configuration which has extra stability.

(*c*) Zn, in Zn ($3d^{10}\ 4s^2$) all the electrons present in *d*-orbitals are paired and hence metallic bonds present in it are weak. That is why, it is soft.

(*ii*) Sodium chromate is acidified with sulphuric acid to give a solution from which orange sodium dichromate, $Na_2Cr_2O_7.2H_2O$ can be crystallised.

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

Sodium dichromate is more soluble than potassium dichromate. The latter is therefore, prepared by treating the solution of sodium dichromate with potassium chloride.

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

Q. 2. (*i*) Is the variability in oxidation number of transition elements different from that of non-transition elements? Illustrate with examples.

(*ii*) Give reasons:

(*a*) *d*-block elements exhibit more oxidation states than *f*-block elements.

(*b*) Orange solution of potassium dichromate turns yellow on adding sodium hydroxide to it.

(*c*) Zirconium (Z = 40) and Hafnium (Z = 72) have almost similar atomic radii.

[CBSE Sample Paper 2017]

Ans. (*i*) In transition elements, the oxidation states differ from each other by unity, *e.g.*, Fe^{3+} and Fe^{2+} etc., while in non-transition elements (*p*-block elements), the oxidation states differ by two, *e.g.*, Pb^{4+} and Pb^{2+}, etc.

In transition elements the higher oxidation states are more stable for the heavier elements in a group, *e.g.*, Mo(VI) is more stable than Cr(VI) whereas in non-transition elements (*p*-block elements), the lower oxidation states are more stable for heavier elements due to inert pair effect, *e.g.*, Pb(II) is more stable than Pb(IV).

(*ii*) (*a*) *d*–block elements exhibit more oxidation states because of less energy gap between *d* and *s* subshell whereas *f*-block elements have large energy gap between *f* and *d* subshell.

(*b*) On adding NaOH, pH of solution increases and the orange colour of the solution changes to yellow due to conversion of dichromate ion to chromate ion.

$$\underset{\text{Dichromate ion (Orange)}}{Cr_2O_7^{2-}} + 2OH^- \rightleftharpoons \underset{\text{Chromate ion (Yellow)}}{2CrO_4^{2-}} + H_2O$$

(*c*) This is due to filling of 4*f*-orbitals which have poor shielding effect (Lanthanoid contraction).

Q. 3. (*i*) Describe the preparation of potassium permanganate from pyrolusite ore. Write balanced chemical equation for one reaction to show the oxidizing nature of potassium permanganate.

(*ii*) Draw the structures of chromate and dichromate ions. ***[CBSE Sample Paper 2017]***

Ans. (*i*) Conversion of pyrolusite (MnO_2) into potassium manganate (K_2MnO_4).

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

Electrolytic oxidation:

$$K_2MnO_4 \rightleftharpoons 2K^+ + MnO_4^{2-}$$

At anode: $MnO_4^{2-} \longrightarrow MnO_4^- + e^-$

At cathode: $H^+ + e^- \longrightarrow H, \quad 2H \longrightarrow H_2$

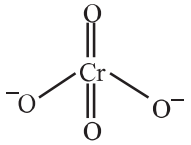
It oxidises oxalate ($C_2O_4^{2-}$) to carbon dioxide (CO_2) in acidic medium.

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

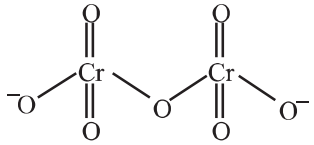
$$C_2O_4^{2-} \longrightarrow 2CO_2 + 2e^-] \times 5$$

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

(*ii*)



Chromate ion



Dichromate ion

Q. 4. **(*i*) Compare non transition and transition elements on the basis of their**

(*a*) Variability of oxidation states

(*b*) Stability of oxidation states.

(*ii*) Give chemical reactions for the following observations:

(*a*) Potassium permanganate is a good oxidising agent in basic medium.

(*b*) Inter convertibility of chromate ion and dichromate ion in aqueous solution depends upon pH of the solution.

(*c*) Potassium permanganate is thermally unstable at 513K. ***[CBSE Sample Paper 2013]***

Ans. (*i*) (*a*) Oxidation states of transition elements differ from each other by unity. In non-transition elements oxidation states normally differ by a unit of two.

(*b*) In transition elements higher oxidation states are favoured by heavier elements whereas in non-transition elements lower oxidation state is favoured by heavier elements.

(*ii*) (*a*) $MnO_4^- + 2H_2O + 3e^- \longrightarrow MnO_2 + 4OH^-] \times 2$

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

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

(*b*) $2CrO_4^{2-} + 2H^+ \underset{\text{Alkali (pH more than 7)}}{\overset{\text{Acid (pH less than 7}}{\rightleftharpoons}} Cr_2O_7^{2-} + H_2O$

(*c*) $2KMnO_4 \xrightarrow{513\ K} K_2MnO_4 + MnO_2 + O_2$

Q. 5. **(*i*) In the titration of $FeSO_4$ with $KMnO_4$ in the acidic medium, why is dil. H_2SO_4 used instead of dil. HCl?**

(*ii*) Give reasons:

(*a*) Among transition metals, the highest oxidation state is exhibited in oxoanions of a metal.

(*b*) Ce^{4+} is used as an oxidising agent in volumetric analysis. ***[CBSE 2019(56/2/3)]***

(*c*) Zn^{2+} salts are white while Cu^{2+} salts are blue.

OR

Why is Cu^{2+} ion coloured while Zn^{2+} ion is colourless in aqueous solution? ***[CBSE 2020 (56/3/1)]***

Ans. (*i*) Dil. H_2SO_4 is an oxidising agent and oxidises $FeSO_4$ to $Fe_2(SO_4)_3$. Dil. HCl is a reducing agent and liberates chlorine on reacting with $KMnO_4$ solution.

Hence, the part of the oxygen produced from $KMnO_4$ is used up by HCl.

(*ii*) (*a*) In these oxoanions the oxygen atoms are directly bonded to the transition metal.

Since oxygen is highly electronegative, the oxoanions bring out the highest oxidation state of the metal.

(*b*) Ce^{4+} has the tendency to attain +3 oxidation state which is more stable and so it is used as an oxidising agent in volumetric analysis.

(*c*) Zn^{2+} ion has all its orbitals completely filled whereas in Cu^{2+} ion there is one half-filled 3*d*-orbital. Therefore, due to *d*-*d* transition Cu^{2+} has a tendency to form coloured salts whereas Zn^{2+} has no such tendency.

Q. 6. **A violet compound of manganese (A) decomposes on heating to liberate oxygen and compounds (B) and (C) of manganese are formed. Compound (C) reacts with KOH in the presence of potassium nitrate to give compound (B). On heating compound (C) with conc. H_2SO_4 and NaCl, chlorine gas is liberated and a compound (D) of manganese along with other products is formed. Identify compounds A to D and also explain the reactions involved.** ***[NCERT Exemplar]*** ***[HOTS]***

Ans. A = $KMnO_4$ (Potassium permanganate), B = K_2MnO_4 (Potassium manganate),

C = MnO_2 (Manganese (IV) oxide), D = $MnCl_2$ (Manganese (II) chloride)

$$\underset{(A)}{2KMnO_4} \xrightarrow{\Delta} \underset{(B)}{K_2MnO_4} + \underset{(C)}{MnO_2} + O_2$$

$$\underset{(C)}{MnO_2} + 2KOH + KNO_3 \longrightarrow \underset{(B)}{K_2MnO_4} + H_2O + KNO_2$$

$$MnO_2 + 4NaCl + 4H_2SO_4 \longrightarrow \underset{(D)}{MnCl_2} + 4NaHSO_4 + 2H_2O + Cl_2$$

Q. 7. When an oxide of manganese (A) is fused with KOH in the presence of an oxidising agent and dissolved in water, it gives a dark solution of compound (B). Compound (B) disproportionates in neutral or acidic solution to give purple compound (C). An alkaline solution of compound (C) oxidises potassium iodide solution to a compound (D) and compound (A) is also formed. Identify compounds A to D and also explain the reactions involved. ***[NCERT Exemplar] [HOTS]***

Ans. A = MnO_2 (Manganese (IV) oxide), B = K_2MnO_4 (Potassium manganate),
C = $KMnO_4$ (Potassium permanganate), D = KIO_3 (Potassium iodate)

$$\underset{(A)}{2MnO_2} + 4KOH + O_2 \longrightarrow \underset{(B)}{2K_2MnO_4} + 2H_2O$$

$$3K_2MnO_4 + 4H^+ \longrightarrow \underset{(C)}{2KMnO_4} + MnO_2 + 2H_2O + 4K^+$$

$$2MnO_4^- + H_2O + KI \longrightarrow \underset{(A)}{2MnO_2} + 2OH^- + \underset{(D)}{KIO_3}$$

Q. 8. (*i*) Write balanced equations to represent what happens when

(*a*) Cu^{2+} is treated with KI.

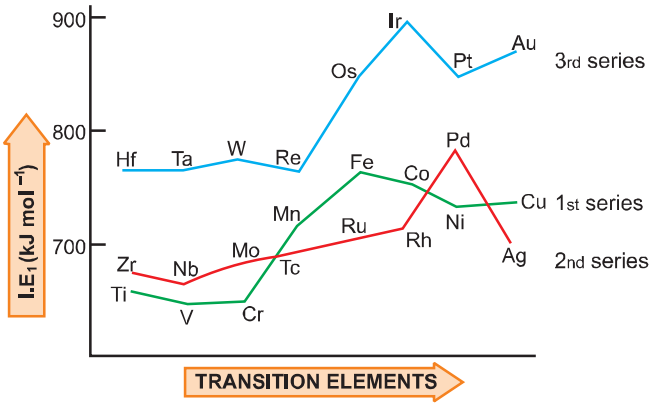
(*b*) Acidified potassium dichromate solution is reacted with iron (II) solution. (ionic equation)

(*ii*) (*a*) The figure given illustrates the first ionization enthalpies of first, second and third series of transition elements. Answer the question that follows:

Which series amongst the first, second and third series of transition elements have the highest first ionization enthalpy and why?

(*b*) Separation of lanthanoid elements is difficult. Explain. ***[CBSE 2020 (56/5/1)]***

(*c*) Sm^{2+}, Eu^{2+} and Yb^{2+} ions in solutions are good reducing agents but an aqueous solution of Ce^{4+} is a good oxidising agent. Why? ***[CBSE Sample Paper 2015]***



Ans. (*i*) (*a*) $2Cu^{2+} + 4I^- \longrightarrow Cu_2I_2 + I_2$

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

$Fe^{2+} \longrightarrow Fe^{3+} + e^-] \times 6$

$$Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \longrightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$$

(*ii*) (*a*) Third series has the highest first ionization energy due to poorest shielding effect of the fully filled 4*f* subshell.

(*b*) Due to lanthanoid contraction, some pair of elements have almost similar size and as a result, such pairs have very similar properties which makes their separation difficult.

(*c*) Sm^{2+}, Eu^{2+} and Yb^{2+} ions are good reducing agents as they tend to acquire common oxidation state of + 3 shown by lanthanoids by the loss of one electron while Ce^{4+} gains one electron to attain + 3. Hence, Ce^{4+} is an oxidising agent.

Q. 9. (*i*) Account for the following:

(*a*) Transition metals form large number of complex compounds. **[*CBSE 2019 (56/2/1)*]**

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

(*c*) E^0 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. **[*CBSE Delhi 2017*]**

Ans. (*i*) (*a*) The tendency to form complex compounds is due to:

—Small size and high charge on metal ion.

—The availability of *d* orbitals for accommodating electrons donated by the ligand.

(*b*) In low oxidation state of the metal, some of the valence electrons of the metal atom are not involved in bonding. Hence, it can donate electrons and behave as a base. On the other hand, in higher oxidation state of the metal, valence electrons are involved in bonding and are not available. Instead effective nuclear charge is high and hence it can accept electrons and behave as an acid.

(*c*) Much large third ionisation energy of Mn (where the required change is stable half filled d^5 to d^4) is mainly responsible for this.

(*ii*) **Similarities**

— Both show mainly an oxidation state of +3.

— Actinoids show actinoid contraction like lanthanoid contraction is shown by lanthanoids.

— Both are electropositive and very reactive. (*Any one*)

Differences

— Except promethium (Pm) lanthanoids are non-radioactive whereas actinoids are radioactive.

— Lanthanoids do not form oxocation whereas actinoids form oxocation.

— Lanthanoids have less tendency towards complex formation whereas actinoids have greater tendency towards complex formation. (*Any one*)

Q. 10. Assign reasons for the following:

(*i*) The enthalpies of atomisation of transition elements are high.

(*ii*) The transition metals and many of their compounds act as good catalysts.

(*iii*) From element to element, the actinoid contraction is greater than the lanthanoid contraction.

(*iv*) The E^0 value for the Mn^{3+}/Mn^{2+} couple is much more positive than that of Cr^{3+}/Cr^{2+}.

(*v*) Scandium ($Z = 21$) does not exhibit variable oxidation states and yet it is regarded as a transition element. **[*CBSE 2019 (56/2/3)*]**

Ans. (*i*) This is because transition metals have strong metallic bonds as they have a large number of unpaired electrons.

(*ii*) The catalytic activity of transition metals is attributed to the following reasons:

(*a*) Because of their variable oxidation states, transition metals form unstable intermediate compounds and provide a new path with lower activation energy for the reaction.

(*b*) In some cases, the transition metal provides a suitable large surface area with free valencies on which reactants are adsorbed.

(*iii*) This is due to poorer shielding by 5*f*-electrons in actinoids than that by 4*f*-electrons in the lanthanoids.

(*iv*) This is due to much larger third ionisation energy of Mn as Mn^{2+} is very stable on account of stable d^5 configuration.

(*v*) This is because scandium has partially filled *d*-orbitals in the ground state ($3d^1\ 4s^2$).

Self-Assessment Test

Time allowed: 1 hour **Max. marks: 30**

Choose and write the correct answer for each of the following. (3 × 1 = 3)

1. **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.
2. **Which element among the lanthanides has the smallest atomic radius?**
   (*a*) Cerium (*b*) Lutetium
   (*c*) Europium (*d*) Gadolinium
3. **In acidic medium, one mole of MnO_4^- ion accepts how many moles of electrons in a redox process?**
   (*a*) 1 (*b*) 2
   (*c*) 5 (*d*) 6

In the following questions, two statements are given—one labeled Assertion (A) and the other labeled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(*a*) *Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).*
(*b*) *Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).*
(*c*) *Assertion (A) is correct, but Reason (R) is incorrect statement.*
(*d*) *Assertion (A) is incorrect, but Reason (R) is correct statement.* (3 × 1 = 3)

4. **Assertion (A) :** Separation of Zr and Hf is difficult.
   Reason (R) : Because Zr and Hf lie in the same group of the periodic table.
5. **Assertion (A) :** Actinoids form relatively less stable complexes as compared to lanthanoids.
   Reason (R) : Actinoids can utilise their 5*f* orbitals along with 6*d* orbitals in bonding but lanthanoids do not use their 4*f* orbital for bonding.
6. **Assertion (A) :** Cu cannot liberate hydrogen from acids.
   Reason (R) : Because it has positive electrode potential.

Answer the following questions:

7. Why lanthanoids are called as *f*-block elements? (1)
8. Name a member of the lanthanoid series which is known to exhibit +4 oxidation state. (1)
9. Account for the following:.
   (*i*) Cobalt (III) is stable in aqueous solution but in the presence of complexing reagents, it is easily oxidised.
   (*ii*) The d^1 configuration is very unstable in ions. (2)
10. Complete the following equations:
    (*i*) $MnO_4^- + 4H^+ + 3e^- \longrightarrow$
    (*ii*) $Cr_2O_7^{2-} + 2OH^- \longrightarrow$ (2)

11. (*i*) Calculate the magnetic moment of a divalent ion in aqueous solution if its atomic number is 25.

(*ii*) While filling up of electrons in the atomic orbitals, the 4*s* orbital is filled before the 3*d* orbital but reverse happens during the ionisation of the atom. Explain why.

[*NCERT Exemplar*] (2)

12. Explain the following observations:

(*i*) Colour of $KMnO_4$ disappears when oxalic acid is added to its solution in acidic medium.

(*ii*) A green solution of potassium manganate turns purple when CO_2 gas is passed through the solution. **(2)**

13. Assign suitable reasons for the following:

(*i*) The Mn^{2+} compounds are more stable than Fe^{2+} towards oxidation to their +3 state.

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

(*iii*) The highest oxidation state is exhibited in oxo-anions of a metal. **[*CBSE (F) 2014*] (3)**

14. When pyrolusite ore MnO_2 is fused with KOH in presence of air, a green coloured compound (*A*) is obtained which undergoes disproportionation reaction in acidic medium to give a purple coloured compound (*B*).

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

(*ii*) What happens when compound (B) is heated? **[*CBSE (South) 2016*] (3)**

15. (*i*) With reference to structural variability and chemical reactivity, write the differences between lanthanoids and actinoids.

(*ii*) Name a member of the lanthanoid series which is well known to exhibit +4 oxidation state.

(*iii*) Out of Mn^{3+} and Cr^{3+}, which is more paramagnetic and why?
(Atomic nos.: Mn = 25, Cr = 24) **(3)**

16. On the basis of lanthanoid contraction, explain the following:

(*i*) Nature of bonding in La_2O_3 and Lu_2O_3.

(*ii*) Trends in the stability of oxo salts of lanthanoids from La to Lu.

(*iii*) Stability of the complexes of lanthanoids.

(*iv*) Radii of 4*d* and 5*d* block elements.

(*v*) Trends in acidic character of lanthanoid oxides. **(5)**

Answers

1. (*b*) **2.** (*b*) **3.** (*c*) **4.** (*b*) **5.** (*d*) **6.** (*a*)