CHAPTER - 07

REDOX REACTIONS

SYNOPSIS

1. **Electronic concept of oxidation and reduction**

   * **Oxidation:** process of loss of electrons by an atomic system

   * **Reduction:** process of gain of electrons by an atomic system

   * **Oxidising agent:** The chemical species which gains electrons and get reduced during the chemical reaction.

   * **Reducing agent:** The chemical species which loses electrons and get oxidised during the chemical reaction.

2. **Concept of oxidation number or oxidation state**

   Oxidation number (O.N.) of an element in a compound is the residual charge which its atom appears to have when all other atoms in a molecule are removed as ions by counting the shared electrons with the more electronegative atom.

3. **Oxidation and reduction in terms of oxidation number**

   * **Oxidation :** Chemical process involving increase in oxidation number

   * **Reduction:** Chemical process involving decrease in oxidation number

   * **Oxidising agent:** Substance which undergoes decrease in oxidation number of one or more of its elements

   * **Reducing agent:** Substance which undergoes increase in oxidation number of one or more of its elements.

4. **Disproportionation**

   It is a process in which the same substance acts as oxidising as well as reducing agent simultaneously

5. **Balancing of chemical equations of redox reactions**

a) Ion - Electron Method (Jette and LaMer)

i) Find O.N. of each element and thus, determine the elements undergoing oxidation/reduction.

ii) Write oxidation and reduction half-reactions putting appropriate number of electrons to reactants or products side.

iii) Balance O atoms in each half reaction by adding the required number of H_2O molecules to the side falling short of O atoms

iv) Balance H atoms, for ionic equation, by adding H^+ ions to the side falling short of H atoms, in case medium is acidic.

v) In case of basic medium, balance H atoms by adding H_2O molecules to the side falling short of H atoms, and equal number of OH^- ions to the other side.

vi) Equalise the number of electrons lost or gained and add the two half-reactions.

b) Oxidation Number Method (Jonson)

i) Write skeleton equation with O.N. of each element.

ii) Determine increase and decrease of O.N. per atom.

iii) Equalise increase and decrease in O.N. on reactant side.

iv) Balance the equation w.r.t. atoms other than H and O atoms.

v) Balance H and O atoms in the similar way as in ion - electron method.

6. **Galvanic cell, Electro Chemical cell or Voltaic cell:** A device which converts chemical energy into electrical energy is called Galvanic, Electrochemical or voltaic cell.

$$M_{(s)} | M^{n+}_{aq} || M^{n+} | M$$

Daniell Cell: An electrochemical cell of Zinc and copper metals is known as Daniell Cell. It is represented as

$Zn_{(s)} | Zn^{2+}_{aq} || Cu^{2+}_{aq} | Cu$

7. **Function of Salt bridge:** (1) Completes the circuit and allows the flow of current (II) It maintain the electrical neutrality on both sides. Salt - bridge generally contains solution of strong electrolyte such as KNO_3, KCl etc. KCl is preferred because the transport numbers of K^+ and Cl^- are almost same.

8. **Electrode Potential:** When an electrode is in contact with the solution of its own ions in a half cell, it has a tendency to lose or gain electrons which is known as electrode potential. It is expressed in volts.

a) Oxidation Potential: The tendency to lose electrons in above case in known as Oxidation potential.

b) Reduction Potential: The tendency to gain electrons in above case is known as reduction potential

c) Standard Reduction Potential $\left(E^{\circ}_{M^{n+}/M}\right)$: Potential under standard state.

9. **Standard hydrogen electrode (SHE):** Standard hydrogen electrode (SHE) also known as Normal Hydrogen Electrode (NHE), consists of platinum wire, carrying platinum foil coated with finely divided platinum black. The wire is sealed into a glass tube, placed in a beaker containing 1M HCl. Hydrogen gas at 1atm pressure is bubbled through the solution at 298K.

Half cell is Pt, H_2(1 atm)/H^+(1M).

In SHE, at the surface of platinum, either of the following reactions can take place.

(i) $2H^+(aq) + 2e^- \rightarrow H_{2(g)}$ Reduction (ii) $H_{2(g)} \rightarrow 2H^+(aq) + 2e^-$ Oxidation

The electrode potential of SHE has been fixed as zero

All other single electrode potentials are referred to as potentials on hydrogen scale

10. **Electromotive force (emf) of a cell :** It is the difference between the electrode potentials of two half cells and cause of flow of current from electrode at higher potential to electrode at lower potential. It is also the measure of free energy change. Standard EMF of a cell

$$E^0_{cell} = E^0_{cathode} - E^0_{anode} = E^0_{right} - E^0_{left}$$

PART-I (JEE MAIN)

SECTION-I- Straight objective type questions

1. When a sulphur atom becomes a sulphide ion

   1) There is no change in the composition of atom

   2) It gains two electrons

   3) The mass number changes

   4) The atomic number changes

2. In the following reaction, $P_4 + 3KOH + 3H_2O \longrightarrow 3KH_2PO_2 + PH_3$,

   1) P is oxidized as well as reduced

   2) P is reduced only

   3) P is oxidized only

   4) P in neither oxidised nor reduced

3. Identify the correct statement about H_2O_2

   1) It acts as reducing agent only

   2) It acts as both oxidizing agent and reducing agent

   3) It is neither oxidising nor reducing

   4) It acts as oxidising agent only

4. When $KMnO_4$ acts as an oxidizing agent, it ultimately forms $[MnO_4]^{2-}$, MnO_2, Mn_2O_3 or Mn^{2+} depending upon pH of the medium. The number of electrons gained by $KMnO_4$ in each of the above cases respectively is

   1) 4, 3, 1, 5 2) 1, 5, 3, 7 3) 1, 3, 4, 5 4) 3, 5, 7, 1

5. In which of the following compounds, does nitrogen exist in +1 oxidation state?

   1) NO 2) N_2O 3) NH_2OH 4) N_2H_4

6. Match List-I with List-II

List-I (Reaction)	**List-II (Type of reaction)**
I) $2H_2O_2 \xrightarrow{\Delta} 2H_2O + O_2$	P) Metal displacement reaction
II) $2NaH \xrightarrow{\Delta} 2Na + H_2$	Q) Disproportionation reaction
III) $V_2O_5 + 5Ca \xrightarrow{\Delta} 2V + 5CaO$	R) Decomposition reaction
IV) $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$	S) Redox reaction

1) $I \rightarrow Q;\ II \rightarrow P;\ III \rightarrow S;\ IV \rightarrow R$ 2) $I \rightarrow QS;\ II \rightarrow PS;\ III \rightarrow PS;\ IV \rightarrow RS$

3) $I \rightarrow QS;\ II \rightarrow RS;\ III \rightarrow S;\ IV \rightarrow RS$ 4) $I \rightarrow QRS;\ II \rightarrow RS;\ III \rightarrow PS;\ IV \rightarrow R$

7. For the redox reaction $MnO_4^- + C_2O_4^{2-} + H^+ \longrightarrow Mn^{2+} + CO_2 + H_2O$, the correct coefficients of MnO_4^-, $C_2O_4^{2-}$ and H^+ are respectively

1) 2, 5, 16 2) 16, 5, 2 3) 5, 16, 2 4) 2, 16, 5

8. How many moles of $K_2Cr_2O_7$ can be reduced by 1 mole of Sn^{2+} in an acidic medium?

1) 1/3 2) 1/6 3) 2/3 4) 1

9. In the balanced chemical reaction, $S_8 + aOH^- \longrightarrow bS^{2-} + cS_2O_3^{2-} + dH_2O$, the value of b and c are respectively

1) 4, 2 2) 2, 3 3) 6, 1 4) 5, $\frac{3}{2}$

10. Given that:

$E^0_{O_2/H_2O} = +1.23V$,

$E^0_{S_2O_8^{2-}/SO_4^{2-}} = +2.05V$,

$E^0_{Br_2/Br^-} = +1.09\ V$,

$E^0_{Au^{3+}/Au} = +1.4V$

The strongest oxidizing agent is:

1) O_2 2) Br_2 3) $S_2O_8^{2-}$ 4) Au^{3+}

11. Strongest reducing agent among the following is

1) F^- 2) Cl^- 3) Br^- 4) I^-

SECTION-II - Numerical Type Questions

12. The oxidation number of middle bromine in Br_3O_8 molecule is .....

13. The oxidation number of oxygen in K_2O, K_2O_2 and KO_2 are –x, –y and –z respectively. Find $\frac{x+y}{z}$

14. In order to oxidise a mixture of 1 mol of each of FeC_2O_4 and $Fe_2(C_2O_4)_3$ in acidic medium, the number of moles of $KMnO_4$ required is ..... $\times 10^{-1}$

PART-II (JEE ADVANCED)

Section-III - Only one option correct type

15. Which of the following compounds contain atleast an element in zero oxidation state?

I) HCHO II) CH_2Cl_2 III) C_3O_2 IV) $S_4O_6^{2-}$

A) I and II B) I, II and III C) I and III D) I, II, III and IV

16. Which of the following can act as oxidising agent as well as reducing agent ?

I) H_2O_2 II) H_2S III) SO_2 IV) HNO_2

A) I, II, III B) II, III, IV C) I, III, IV D) All

17. Standard reduction potential of three metals X, Y and Z are +0.52 V, –2.87 V and –0.44 V respectively. The reducing power of metals are in the order

A) Y > Z > X B) X > Y > Z C) Y > X > Z D) X > Z > Y

18. In the reaction, $8Al + 3Fe_3O_4 \longrightarrow 4Al_2O_3 + 9Fe$, the total number of electrons transferred from reductant to oxidant is

A) 8 B) 4 C) 7 D) 24

19. Equivalent weight of H_3PO_2 when it disporoportionates into PH_3 and H_3PO_3 is (M is the molecular weight of H_3PO_2)

A) M B) M/2 C) M/4 D) 3M/4

Section IV - One or more option correct type

20. Which of the following is/are not disproportionation reaction(s)?

A) $(NH_4)_2Cr_2O_7 \longrightarrow N_2 + Cr_2O_3 + 4H_2O$

B) $5H_2O_2 + 2ClO_2 + 2OH^- \longrightarrow 2Cl^- + 5O_2 + 6H_2O$

C) $3ClO^- \longrightarrow ClO_3^- + 2Cl^-$

D) $2HCuCl_2 \xrightarrow[\text{water}]{\text{Dilution with}} Cu + Cu^{2+} + 4Cl^- + 2H^+$

21. In which of the following species, central atom is present in its highest oxidation state?

A) OsO_4 B) XeO_6^{4-} C) CrO_5 D) K_2MnO_4

22. Which of the following ions will not undergo disproportionation?

A) SO_4^{2-} B) MnO_4^{2-} C) CrO_4^{2-} D) ClO_2^-

23. 100 mL of of 0.1 M $Ca(MnO_4)_2$ in acidic medium can be oxidised completely with

A) 100 mL of 1 M $FeSO_4$ solution B) $\frac{100}{3}$ mL of 1 M FeC_2O_4 solution

C) 25 mL of 1 M $K_2Cr_2O_7$ solution D) 75 mL of 1 M $K_2C_2O_4$ solution

24. In basic medium, CrO_4^{2-} oxidises $S_2O_3^{2-}$ to form SO_4^{2-} and itself changes to $Cr(OH)_4^-$. Select the correct statement(s)

A) The volume of 0.154 M CrO_4^{2-} required to react with 40 mL of 0.25 M $S_2O_3^{2-}$ is about 173 mL

B) Each mole of CrO_4^{2-} is reduced by $\frac{3}{8}$ moles of $S_2O_3^{2-}$

C) The volume of 0.50 M $S_2O_3^{2-}$ required to react with 173 mL of 0.154 M CrO_4^{2-} is about 86.5 mL

D) Each mole of $S_2O_3^{2-}$ is reduced by $\frac{3}{8}$ moles of CrO_4^{2-}

Section V - Numerical type questions

25. Number of electrons taken up by nitrogen atom when a nitrosonium ion (NO^+) is reduced to hydroxylamine (NH_2OH) is .....

26. The difference in oxidation number of two nitrogen atoms in the ammonium nitrate (NH_4NO_3) is .....

27. A solution containing 2.68 × 10^{-3} mol of A^{n+} ions requires 1.61×10^{-3} mol of MnO_4^- for the complete oxidation of A^{n+} to AO_3^- in acidic medium. What is the value of n ?

28. 1 mole of IO_3^- ions is heated with excess of I^- ions under acidic conditions. The reaction is represented as $IO_3^- + I^- \rightarrow I_2$. How many moles of sodium thiosulhpate ($Na_2S_2O_3$) will be required (under acidic conditions) to react completely with I_2 thus produced ?

29. 1 L of 0.1 M $Ba(MnO_4)_2$ in acidic medium can be oxidised completely with $\frac{1}{6}$ L of x M ferric oxalate. The value of x is .....

Section-VI - Matrix match type

30. Match the column-I with column-II

Column-I (Compound)	**Column-II (Oxidation state of nitrogen)**
I) Mg_3N_2	P) –1
II) NO	Q) +2
III) $(N_2H_5)_2SO_4$	R) –2
IV) NH_2OH	S) –3

A) $I \rightarrow S;\ II \rightarrow Q;\ III \rightarrow Q;\ IV \rightarrow P$

B) $I \rightarrow Q;\ II \rightarrow Q;\ III \rightarrow P;\ IV \rightarrow R$

C) $I \rightarrow S;\ II \rightarrow Q;\ III \rightarrow R;\ IV \rightarrow P$

D) $I \rightarrow Q;\ II \rightarrow Q;\ III \rightarrow Q;\ IV \rightarrow R$