Chapter 7 Solutions and Electrolytes

Multiple Choice Questions (M.C.Qs)

Choose the correct answer for each from the given options:

01 ***Metals place above hydrogen in the electrochemical series:***
(a) undergoes oxidation (b) undergoes reduction
(c) serve at cathode in comparison cell (d) have positive electrode potential

02 ***The colour of the universal indicator in base solution is:***
(a) yellow (b) green (c) orange (d) purple

03 ***The oxidation number of Mn in $KMnO_4$ is:***
(a) + 3 (b) + 5 (c) + 7 (d) + 4

04 ***In this, electric current is produced by an oxidation reduction process:***
(a) standard cell (b) voltaic cell (c) reversible cell (d) electrolytic cell

05 ***Among these solutions, this one has the highest pH value:***
(a) 0.01M NaOH (b) 0.02M HCl (c) 0.01M $NaHCO_3$ (d) 0.10M H_2SO_4

06 ***The component that predominates in the solution is referred to as:***
(a) solute (b) solvent (c) ions (d) hydration

07 ***In electrolytic cell, the anode is the electrode where:***
(a) oxidation occurs (b) reduction occurs
(c) both oxidation & reduction occurs (d) neutralization occurs

08 ***The number of gram moles of solute present in 1 dm^3 of solution is called:***
(a) normality (b) molarity (c) mole fraction (d) molality

09 ***The oxidation number of oxygen in hydrogen peroxide is:***
(a) + 2 (b) - 2 (c) + 1 (d) - 1

10 ***The range of pH is:***
(a) 1 - 10 (b) 0 - 20 (c) 1 - 100 (d) 0 - 14

11 ***In electrolytic cell, cathode is:***
(a) negative (b) positive (c) neutral (d) none of these

12 ***An electrochemical cell is based upon:***
(a) acid -base reaction (b) redox reaction
(c) oxidation reaction (d) reduction reaction

13 ***In solution conduction is due the:***

(a) movement of ions (b) movement of electrons
(c) movement of protons (d) movement of atoms

14 ***If 200 cm³ of 1M solution is diluted up to 200 cm³ its molarity would be:***

(a) 10M (b) 0.2M (c) 0.1M (d) 1M

15 ***Types of solutions are:***

(a) 9 (b) 7 (c) 5 (d) 3

16 ***If pH of a solution is zero the nature of solution will be:***

(a) acidic (b) basic (c) neutral (d) amphoteric

17 ***A solution in which water is solvent is termed as:***

(a) aqueous (b) alcoholic (c) etheral (d) none of the above

18 ***Which one is an electrolyte?***

(a) $AgNO_3$ Solution (b) Ethanol (c) Mercury (d) Sugar solution

19 ***The amount of solute present in a given amount of solvent is called:***

(a) concentration (b) solubility product (c) common ion (d) hydrolysis

20 ***The number of moles of solute dissolve per kg (1000gm) of solvent is called:***

(a) molarity (b) molality (c) mole fraction (d) normality

21 ***The process in which water molecules get attached to the ions of salt is called:***

(a) hydrolysis (b) hydration (c) electrolysis (d) precipitation

22 ***When an electric current is passed through a solution of electrolyte, anions move towards:***

(a) cathode (b) electrode (c) anode (d) cation

23 ***The pH of a solution is mathematically expressed as:***

(a) $pH = -\log [H^+]$ (b) $pH = [H^+]$

(c) $pH = \frac{1}{[H^+]}$ (d) $pH = 2 [H^+]$

24 ***If pH of a solution is less than 7, the solution will be:***

(a) neutral (b) alkaline (c) acidic (d) amphoteric

25 ***Solutions which tend to maintain their pH when an acid or base is added is termed as:***

(a) molar solutions (b) ideal solution (c) buffer solution (d) saturated solution

26 ***Oxidation involves:***

(a) gain of electron (b) loss of electron
(c) decrease in oxygen (d) none of them

27 ***Oxidation number of Cl in $KClO_3$ is equal to:***

(a) - 1 (b) - 5 (c) + 5 (d) - 6

28 ***Oxidation number of Cr in $K_2Cr_2O_7$ is:***

(a) + 12 (b) + 6 (c) - 6 (d) - 3

29 ***Which one of the following aqueous solution will be base in character:***

(a) NaCl (b) Na_2CO_3 (c) $FeCl_3$ (d) NH_4Cl

30 ***$Na_2CO_3 + 2H_2O \longrightarrow 2NaOH + H_2CO_3$, this reaction is called:***

(a) hydration (b) hydrolysis (c) neutralization (d) dissociation

31 ***The reaction in which hydrogen ions of acid and hydroxide ions of alkali react together to produce water is called:***

(a) hydrolysis (b) hydration (c) neutralization (d) ionization

32 ***Blood has a pH of about:***

(a) 6.2 (b) 7.9 (c) 7.3 (d) 14.0

33 ***The degree of ionization depends upon:***

(a) quantity of H_2O (b) speed of ions (c) temperature (d) nature of electrolyte

34 ***The ability of an ion to form hydrate depends upon:***

(a) hydrolysis (b) ionization (c) charge density (d) crystallization

35 ***In case of NaCl, the hydrolysis:***

(a) occurs on certain conditions (b) sometime occurs
(c) always occurs (d) does not occur

36 ***The process in which atom gains an electron is called:***

(a) oxidation (b) reduction (c) neutralization (d) radiation

37 ***Molarity of a solution is expressed in:***

(a) moles / kg (b) g / dm^3 (c) dm^3 / mol (d) mol / dm^3

38 ***Weak electrolytes show low conductance due to their low degree of :***

(a) hydrolysis (b) hydration (c) ionization (d) dilution

39 ***The process in which water reacts chemically with salt is called:***

(a) neutralization (b) hydrolysis (c) hydration (d) solvation

40 ***For strong acid and weak base titration the suitable indicator is:***

(a) phenolphthalein (b) methyl orange (c) litmus (d) $KMnO_4$

41 ***In solution, the number of water molecules surrounds the ions are:***

(a) indefinite (b) zero (c) definite (d) none of them

42 ***Which of the following has greater charge density?***

(a) K^+ (b) Al^{+3} (c) O^{-2} (d) Br^-

43 ***Oxidation number of oxygen is +2 in:***

(a) Na_2O (b) Na_2O_2 (c) F_2O (d) Cl_2O

44 ***The oxidation number of hydrogen when combined with a metal of lower E.N. is:***

(a) + 2 (b) - 2 (c) + 1 (d) - 1

45 ***When a non- spontaneous redox reaction is carried out by using the electrical current then process is called:***

(a) decomposition (b) hydrolysis (c) cracking (d) electrolysis

46 ***Reduction is a chemical change in which:***

(a) ions are lost (b) ions are gained (c) electrons are lost (d) electrons are gained

47 ***The electropotential of standard hydrogen electrode is taken as:***

(a) positive value (b) negative value (c) zero (d) fraction value

48 ***The colour of phenolphthalein in acidic medium is:***

(a) pink (b) purple (c) colourless (d) orange

49 ***The following is an example of oxidation reduction:***

(a) $Ag^+ + Cl^- \longrightarrow AgCl$ *(b)* $H_2O \longrightarrow H^+ + OH^-$

(c) $Cl + e^- \longrightarrow Cl^-$ *(d)* $Na \longrightarrow Na^+ + e^-$

50 ***What is the oxidation number of 'S' in sulphuric acid:***

(a) - 2 (b) + 2 (c) + 4 (d) + 6

51 ***The oxidation number of an uncombined element is always:***

(a) 0 (b) 1 (c) 2 (d) 3

52 ***The potential difference created between a metal and its ions is called:***

(a) anode (b) cathode

(c) electrode Potential (d) electrode

53 ***Ionic compounds conduct electric current when they are in:***

(a) solid state (b) molten form (c) frozen form (d) dehydrated form

54 ***As a result of electrolysis of a dilute solution of NaCl, this will form on the cathode:***

(a) sodium (b) chlorine (c) hydrogen (d) oxygen

55 $Zn_{(s)} - 2e \longrightarrow Zn^{2+}$ ***. It is:***

(a) oxidation (b) reduction (c) ionization (d) hydration

56 ***pH of milk is:***

(a) 6.6 (b) 7.0 (c) 7.3 (d) 7.9

57 ***pH of blood is:***

(a) 6.6 (b) 7.0 (c) 7.3 (d) 10.5

58 ***pH of*** H_2SO_4 ***is:***

(a) 1.0 (b) 1.2 (c) 6.6 (d) 7.3

59 ***pH of blood is 7.3. It is:***

(a) acidic (b) neutral (c) basic (d) none of them

60 ***pH of sea water is:***

(a) 7.9 (b) 8.0 (c) 8.4 (d) all of them

61 ***Conversion of*** Sn^{+2} ***to*** Sn^{+4} ***is***

(a) physical (b) mechanical (c) oxidation (d) reduction

62 ***Oxidation number of N in*** HNO_3 ***is:***

(a) + 1 (b) + 3 (c) - 3 (d) + 5

63 ***During electrolysis oxidation occurs at:***

(a) anode (b) cathode (c) both electrodes (d) none of the above

64 ***In this equation*** $K_a = \frac{[A^+][B^-]}{[AB]}$ ***,*** K_a ***is called:***

(a) equilibrium constant (b) solubility

(c) molarity (d) dissociation constant

65 ***Phenolphthalein gives pink color in:***

(a) acid (b) base (c) neutral (d) none of the above

66 ***A mixture of*** CH_3OOH ***and*** CH_3COONa ***is called:***

(a) alkaline solution (b) basic Solution (c) buffer solution (d) all of these

67 $CuSO_4 + 5H_2O \longrightarrow CuSO_4.5H_2O$ this reaction is an example of :
(a) hydrolysis (b) neutralization (c) hydration (d) dehydration

68 The passage of current in an electrolyte is due to the movement of :
(a) electrons (b) ions (c) molecules (d) atoms

69 Homogenous mixture of solute and solvent is called:
(a) solubility (b) dilution (c) solution (d) chemical reaction

70 Ionic theory of electrolysis was given by :
(a) Levies (b) Arrhenius (c) Bronsted (d) Debye

71 Which one of the following does not conduct electricity in an aqueous solution?
(a) KNO_3 (b) CH_3OH (c) KOH (d) CH_3COOH

72 The oxidation number of Fe in $FeCl_3$ is:
(a) + 4 (b) + 2 (c) + 3 (d) + 1

73 Indicator phenolphthalein is a weak :
(a) base (b) acid (c) salt (d) none of these

74 The solvent that termed as universal solvent is :
(a) benzene (b) carbon tetrachloride
(c) alcohol (d) water

75 Weak electrolytes show low conductance due to their low degree of :
(a) dilution (b) ionization (c) concentration (d) precipitation

76 The difference of potential created between a metal and its salt solution is called:
(a) cathode potential (b) anode potential
(c) electrode potential (d) none of the these

77 The molarity of a solution containing 4 gm NaOH dissolved in 10 ml solution is:
(a) 0.4 M (b) 0.1 M (c) 10 M (d) 1.0 M

Answer Key

1. (a)	12. (b)	23. (a)	34. (c)	45. (d)	56. (a)	67. (c)
2. (d)	13. (a)	24. (c)	35. (d)	46. (d)	57. (c)	68. (b)
3. (c)	14. (c)	25. (c)	36. (b)	47. (c)	58. (b)	69. (c)
4. (d)	15. (a)	26. (b)	37. (d)	48. (c)	59. (c)	70. (b)
5. (d)	16. (a)	27. (c)	38. (c)	49. (d)	60. (d)	71. (b)
6. (b)	17. (a)	28. (b)	39. (b)	50. (d)	61. (c)	72. (c)
7. (a)	18. (a)	29. (b)	40. (b)	51. (a)	62. (d)	73. (b)
8. (b)	19. (a)	30. (b)	41. (a)	52. (c)	63. (a)	74. (d)
9. (d)	20. (b)	31. (c)	42. (b)	53. (b)	64. (d)	75. (b)
10. (d)	21. (b)	32. (c)	43. (c)	54. (a)	65. (b)	76. (c)
11. (a)	22. (c)	33. (d)	44. (d)	55. (a)	66. (c)	77. (c)

Short / Detailed Answer Questions

Q.01 Define Solution.

Ans. Solutions are homogenous mixture or single phase mixtures of molecules, atoms or ions of two or more substances. It is comprises of two parts:

Solute + Solvent ⟶ Solution

For example, Sugar + water ⟶ Sugar Solution

Q.02 Define solute and solvent.

Ans. ***Solute:*** The component of the solution present in smaller amount is called solute.

Solvent: The component of the solution which is present in large quantity is called the solvent.

Example: In a sugar solution water is solvent and sugar is solute.

Q.03 State types of solution with examples.

Ans. There are nine possible types of solution consisting of mixture of gases, liquids and solids.

SOLUTE	SOLVENT	EXAMPLES
Gas	Gas	
Gas	Liquid	Air aerated water (cold drinks)
Gas	Solid	H_2 in palladium.
Liquid	Gas	Water (Vapour) in air; rose scent in air.
Liquid	Liquid	Alcohol in water.
Liquid	Solid	Hg in Na (amalgam)
Solid	Gas	Smoke (carbon particles in air)
Solid	Liquid	Glucose in water.
Solid	Solid	Alloys (Cu + Sn) called Bronze.

Q.04 Define concentration and give its types. *Karachi Board: 2005, 2006, 2007, 2011*

Ans. ***Concentration:*** In a given solution, the given amount of solute dissolved in a unit volume of a solution (or a unit amount of solvent) is known as the concentration of the solution.

(i) ***Dilute Solution:*** Solution containing relatively lower concentration of solute is called dilute solution.

(ii) ***Concentrated Solution:*** A solution containing relatively higher concentration of solute is called concentrated solution.

Units of the Concentration of Solutions:

As the amount of solute, solvent or solution are measured by volume, weight or number of moles, therefore concentration of the solution may be expressed in many ways:

(I) Percentage composition (ii) Molarity (iii) Molality
(iv) Mole fraction (v) Normality

Q.05 ***What are physical units of concentration? Explain with example.***

Ans. ***Percentage composition:*** The amount of solute and solvent can be expressed in percentage composition by four different ways:

(a) Percentage weight by weight (W/W)
(b) Percentage weight by volume (W/V)
(c) Percentage volume by weight (V/W)
(d) Percentage Volume by Volume (V/V)

Examples:

(i) 20 grams of NaOH per cubic decimeter (dm^3) of solution (W/V).
(ii) 10% aqueous solution of NaCl contains 10g NaCl per 100g solution i.e., 10g NaCl mixed with 90 grams of water (W/W).

Q.06 ***Describe molarity. Give its mathematical formula with an example of a molar solution.***

Ans. ***Molarity:*** Molarity is the number of moles of solute dissolved per litre (dm^3) of the solution. Its symbol is 'M'.

Mathematical formulas:

$$\text{Molarity (M)} = \frac{\text{No. of moles of Solute}}{\text{Volume of Solution in } dm^3}$$

$$\text{Molarity (M)} = \frac{\text{Mass of Solution in gms} \times 1000}{\text{Molecular mass of solute} \times \text{Volume of Solution in } cm^3}$$

Examples:

(i) 0.5 molar solution of Na_2CO_3 contains 53 grams of Na_2CO_3 / dm^3 of solution.
(ii) One molar (1M) solution contains 106g Na_2CO_3 (molecular wt of Na_2CO_3) per dm^3 of solution. The term molarity is often used to refer to molar concentration.

Q.07 ***Describe molality. Give its mathematical formula with an example of a molal solution.***

Ans. ***Molality (m):*** Molality is the type of concentration. It is the number of moles of solute dissolved per kg of the solvent.

Mathematical Formulae:

$$\text{Molarity (M)} = \frac{\text{No. of moles of Solute}}{\text{Mass of solvent in Kg}}$$

or

$$\text{Molarity (M)} = \frac{\text{Mass of solute in grams} \times 1000}{\text{Molar mass of solute} \times \text{Mass of solvent in gms}}$$

Examples:

(i) A molal solution (1 m) of Na_2CO_3 contains 106g of Na_2CO_3 dissolved in 1000g of water.

(ii) 0.5 molal solution contains 53g Na_2CO_3 per kg of water.

The term molality is often used to refer to molal concentration.

Q.08 ***Briefly describe the process of hydration.*** ***Karachi Board: 2005, 2008, 2010***

Ans. ***Hydration:*** Water dissolves majority of the substances. Some of these substances may be re-crystallized from their solutions retaining some molecules of water as the part of the crystal lattice. These solid crystalline substances are known as hydrates and the process is called hydration. In hydration process, water molecules as such are linked with crystal lattice. No H - O bonds of water are broken although new bonds are formed.

Examples: $BaCl_2.2H_2O$, $CuSO_4.5H_2O$, $FeSO_4.7H_2O$, $AlCl_3.6H_2O$ etc.

These water molecules which are physically attached with salt are called water of crystallization.

Q.09 ***Define water of crystallization. Explain the ability of ions to from hydrates.***

Ans. ***Water of Crystallization:*** Definite number of water molecules present in the crystal of a substance is called water of crystallization.

e.g., $CuSO_4.5H_2O$

Ability to from Hydrates:

The ability of an ion to form hydrate depends upon the charge density i.e., size of the ion and its charge.

Example: When aqueous solution of a salt is evaporated, the salt crystallizes with definite number of water molecules called water of crystallization.

An ion with higher charge density has greater ability to attract water molecules. In $CuSO_4.5H_2O$, size of Cu^{++} ion is smaller than SO_4^{-2} ion, therefore charge density of Cu^{++} is greater than that of SO_4^{-2} this is why out of five water molecules of crystallization four are attracted by Cu^{++} ion and only one is attracted by SO_4^{-2} ion. This small positive ions with multiple charges such as Cu^{2+}, Al^{3+}, Cr^{3+} possess great attraction for water molecules.

Q.10 ***Write a note on hydrolysis.*** ***Karachi Board: 2006, 2007, 2008, 2010***

Ans. ***Definition:*** When a salt dissolve in water, it is dissociated into cations and anions. The process in which cations or anions or both react with water, which is used as solvent, is called hydrolysis.

Explanation of Hydrolysis:

Cations of strong bases and anions of strong acids do not undergo hydrolysis. For example Na^+, K^+, Cl^-, NO_3^-.

Similarly neither the cations nor the anions of the salt of strong acids and strong bases undergo hydrolysis. This is why their solutions remain neutral such as NaCl.

Different salts upon dissolving in water, do not always form neutral solutions such as NH_4Cl, $AlCl_3$, $CuSO_4$, give acidic solution in water on the other hand Na_2CO_3 and CH_3COONa form basic solutions in water. These interaction between salts and water are called hydrolytic reactions and the phenomenon is known as hydrolysis.

(i) $NH_4Cl + H_2O \longrightarrow NH_4OH_{(aq)} + HCl_{(aq)}$

(ii) $Na_2CO_3 + 2H_2O \longrightarrow 2NaOH_{(aq)} + H_2CO_{3(aq)}$

Strong base — Weak acid

Q.11 ***Write down the postulates of the Arrhenius theory of ionization.***

Ans. ***Karachi Board: 2008-2009-2012-2015-2019***

Arrhenius put forward a comprehensive theory of ionization in 1884, this theory explained not only the mechanism of electrolytic conduction but also gave clear explanation of various phenomena like higher value of osmotic pressure, depression of freezing point, elevation of boiling point, ionic reaction etc.

The main postulates of this theory are as under:

(1) Acids, bases and salt when dissolved in water give two kinds of particles, one carrying a positive charge and the other one carry equal but opposite charge (negative), these charged particles are called IONS.

$$H_2SO_4 \xrightarrow{H_2O} 2H^+_{(aq)} + SO_2^{-2}$$

$$NaOH \xrightarrow{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

$$NaCl \xrightarrow{H_2O} Na^+_{(aq)} + Cl^-_{(aq)}$$

(2) In solutions, the ions constantly collide to form neutral molecules. Thus ionization is a reversible process and there is a state of equilibrium between this dissociated and un-dissociated molecules, thus:

$$AB \rightleftharpoons A^+ + B^-$$

Applying the law of mass action to the above equilibrium:

$$\frac{[A^+]\,[B^-]}{[AB]} = K \quad \text{(dissociation constant)}$$

(3) On passing electric current through the solution of an electrolyte the +ve ions (cations) move towards the cathode and the -ve ions (anions) towards the anode. On reaching the electrodes the ions lose their charge(s) and change into neutral species (atoms or molecules). It is the movement of ions which allows electricity to pass through the solution of the electrolyte.

(4) The extent to which an electrolyte dissociates into ions is known as "degree of dissociation" which depends upon:

- ***(a)*** ***Nature of electrolytes:*** Strong acids, strong bases and salts are almost completely ionized. Weak acids, weak bases and their salts are weakly ionized.
- ***(b)*** ***The nature of the solvents:*** The solvents which have polarity, ionize the electrolytes to a marked degree.
- ***(c)*** ***Temperature:*** The higher the temperature greater is the ionization.
- ***(d)*** ***Degree of dilution:*** Greater the degree of dilution, greater would be the ionization.

(5) The properties of electrolytes in solution are the properties of the ions. Acidic properties are due to H^+ ions and basic properties are due to OH^- ions and the chemical properties of salts are due to the ions forming them.

(6) The ions behave like molecules which affect the physical properties like freezing point, boiling point etc. If an electrolyte forms two ions, it will increase osmotic pressure two fold and the other yielding three ions that molecule will exert the normal effect.

Q.12 ***Define electrolysis.*** ***Karachi Board: 2010, 2011, 2012, 2014, 2017, 2018***

Ans. ***Electrolysis:*** The ions exist in solution before the passage of electric current. When no electric current is passed the ions move about randomly.

Definition: The movement of ions towards their respective electrodes on passing electro current, accompanying all chemical changes in an electrolytic solution under the influence of an applied electric field is known as electrolysis or electrolytic conduction.

Q.13 ***What are electrodes?*** ***Karachi Board: 2011***

Ans. An electro-conducting substance which when placed in an electrolyte develops certain electrical potential with respect to the bulk of solution. Positive electrode is called anode and the negative electrode is called cathode.

e.g., Copper electrode, Zn electrode etc.

Q.14 ***What are electrolytes?*** ***Karachi Board: 2011***

Ans. The substances which can allow the electric current to pass through them in the solution state or molten state are called electrolytes. Acids, bases and salts are electrolytes. For example, H_2SO_4, NaOH and NaCl are the examples of electrolytes.

Q.15 ***Explain the process of electrolysis of $CuCl_2$ solution in an electrolytic cell.***

Ans. ***Karachi Board: 2010, 2014, 2017, 2018***

Electrolytic Cell:

When electricity is passed through an electrolyte in the molten or aqueous state, anions begin to move towards anode (i.e. positively charged electrode) where as cations begin to move towards cathode (i.e. negatively charged electrode). Oxidation takes place at the anode which removes electrons from the anions whereas reduction takes place at the cathode which provides electrons to the cations. The electrons removed by the anode are pumped out by the source of electric potential and transferred to cathode.

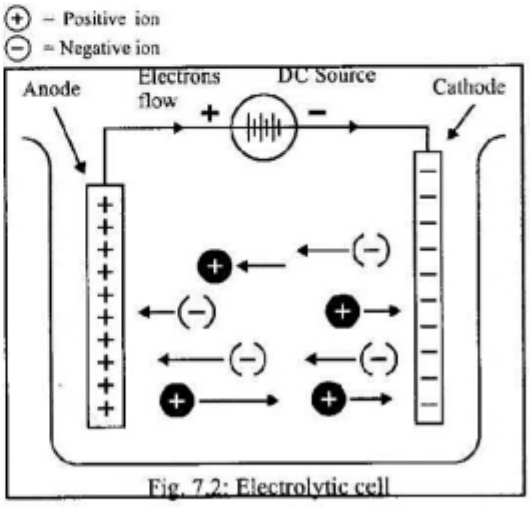

Fig. 7.2: Electrolytic cell

The Electrolysis of solution of cupric chloride ($CuCl_2$):

On dissolving in water, these ions are separated:

$$CuCl_{2(aq)} \rightleftharpoons Cu^{2+}_{(aq)} + Cl^{-}_{(aq)}$$

These ions are free to move randomly among water molecules when no electric current is passing. As soon as the electric current is passed, the movement of these ions to take place Cu^{2+}

ions migrate towards cathode and Cl^- ions towards anode. At cathode, Cu^{2+} ions are discharged as copper atoms by the gain of electrons (reduction):

$$Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)} \quad \text{(Reduction at cathode)}$$

At anode, Cl^- ions are discharged as Cl_2 gas by the loss of electrons (oxidation):

$$2Cl^-_{(aq)} - 2e^- \longrightarrow Cl_{2(g)} \quad \text{(Oxidation at anode)}$$

Thus the reactions taking place in the electrolytic cell are oxidation - reduction reactions or redox reaction. By combining the electrode reactions, the over all reaction of the electrolysis is obtained as:

$$Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$$
$$2Cl^-_{(aq)} - 2e^- \longrightarrow Cl_{2(g)}$$
$$Cu^{2+}_{(aq)} + 2Cl^-_{(aq)} \longrightarrow Cu_{(s)} + Cl_{2(g)}$$

$$CuCl_{2(aq)} \longrightarrow Cu_{(s)} + Cl_{2(g)}$$

When the ions originally present have been changed to neutral particles, the current can no longer flow.

Q.16 ***Write detailed note on electrode potential.*** ***Karachi Board: 2005, 2007, 2008, 2012, 2013, 2018***

Ans. ***Definition of electrode potential:*** The difference of potential created between a metal and solution of its salt is called electrode potential of the metal. It is a measure of tendency of an electrode to lose or gain electrons.

(a) Oxidation potential:

The tendency of a metal (element) to get oxidized is called oxidation potential. If the reaction is represented as:

$$M \longrightarrow M^+ + e^-$$

Then the oxidation potential is written as:

$$E^\circ_{oxidation} = \frac{M}{M^+} \quad \text{(i)}$$

(b) Reduction potential:

The tendency of a metal to get reduced is called reduction potential. The reaction is represented as:

$$M^+ + e^- \longrightarrow M$$

Then the reduction potential is written as:

$$E^\circ_{reduction} = \frac{M^+}{M} \quad \text{(ii)}$$

The reactions (i) and (ii) differ only in direction and therefore oxidation potential and reduction potential have same magnitude but different signs.

$$E^\circ_{oxidation} = -E^\circ_{reduction}$$

$$\text{Total potential (voltage)} = E^\circ_{oxidation} + E^\circ_{reduction}$$

Q.17 ***Define standard electrode potential.*** ***Karachi Board: 2012-2013-2015-2016-2019***

Ans. The potential set up when an electrode is in contact with one molar solution of its own ions at 298K is called standard electrode potential or standard reduction potential of the element. It is represented as E°.

Q.18 ***Write down a note on standard hydrogen electrode. (SHE).***

Ans. ***Standard Hydrogen Electrode:***

A standard hydrogen electrode consists of a platinum foil coated with a layer of finally divided platinum. It is encased with a glass sleeve with hydrogen gas passing through it at 1 atm pressure. It is then immersed in 1 M HCl solution. Reduction potential of SHE in arbitrarily taken as zero. (See fig 7.3)

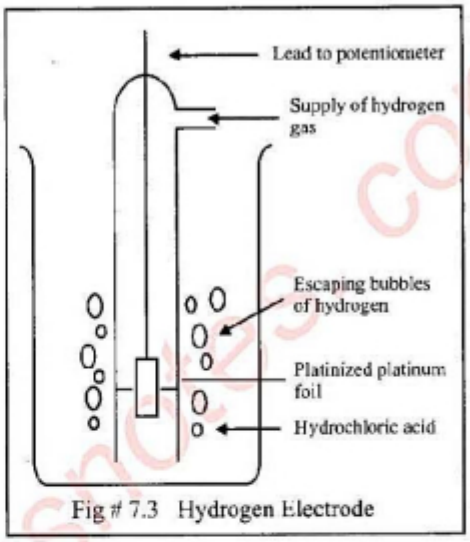

Fig # 7.3 Hydrogen Electrode

SHE acts as anode when it is combined with the electrode having greater reduction potential than 0.000. For example, SHE acts as anode when it is combined with copper electrode. In this case oxidation will take place at SHE.

$H_2 \longrightarrow 2H^+ + 2e^-$ (Oxidation half reaction)

SHE acts as cathode when it is combined with the electrode having less reduction potential than 0.000. For example, SHE acts as cathode when it is combined with Zn electrode. In this case reduction will take place at SHE.

$2H^+_{(aq)} + 2e^- \longrightarrow H_{2(g)}$ $E^\circ = 0.00V$ (Reduction half reaction)

She is used as reference electrode to determine the reduction potential of different electrodes.

Q.19 ***How is the electrode potential of Zn determined?*** ***Karachi Board: 2008, 2011, 2012, 2018***

Ans. ***Measurement of reduction / oxidation potential of zinc electrode:***

Combine standard hydrogen electrode with zinc electrode. Connect these two electrodes properly with voltmeter. It shows + 0.76 V E° cell. When zinc electrode is connected with the negative terminal of the voltmeter and SHE is connected with the positive terminal of the voltmeter, it shows that zinc electrode acts as anode where as SHE acts as cathode. It means oxidation will take place at zinc electrode and reduction will take place at standard hydrogen electrode (SHE).

$Zn \longrightarrow Zn^{2+} + 2e^-$

$2H^+ + 2e^- \longrightarrow H_2$

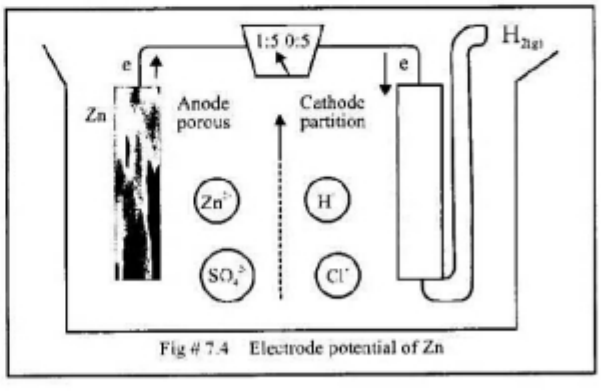

Fig # 7.4 Electrode potential of Zn

Use the following formula to calculate the reduction.

Potential of zinc electrode:

$E^\circ_{cell} = E^\circ_{subreduced} - E^\circ_{suboxidized}$

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

$E^\circ_{cell} = E^\circ_{H_2} - E^\circ_{Zn}$

$0.76\,V = 0.00\,V - E^\circ_{Zn}$

$E^\circ_{Zn} = -0.76\,V$

Q.20 ***How is the electrode potential of copper determined?*** ***Karachi Board: 2013-2019***

Ans. ***Measurement of reduction / oxidation potential of copper electrode:***

Combine SHE with copper electrode. Connect these two electrodes properly with voltmeter.

voltmeter. It shows + 0.34 V E° "cell" when standard hydrogen electrode is connected with the negative terminal of the voltmeter and copper electrode is connected with the positive terminal of the voltmeter. This shows that standard hydrogen electrode acts as anode whereas copper electrode acts as cathode. It means oxidation will take place at SHE and reduction will take place at copper electrode.

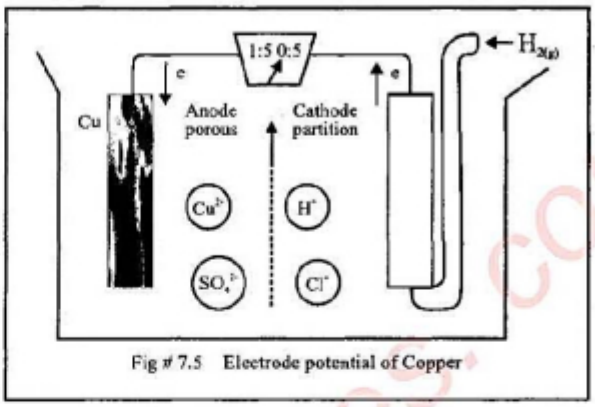

Fig # 7.5 Electrode potential of Copper

$H_2 \longrightarrow 2H^+ + 2e^-$ (oxidation half reaction)

$Cu^{2+} + 2e^- \longrightarrow Cu$ (reduction half reaction)

Use the following formula to calculate the reduction potential of copper electrode.

$E°_{cell} = E°_{subreduced} - E°_{suboxidized}$

$E°_{cell} = E°_{cathode} - E°_{anode}$

$E°_{cell} = E°_{Copper} - E°_{hydrogen}$

$0.34\,V = E°_{Cu} - 0.00V$

$E°_{Cu} = -0.34\,V$

Q.21 ***What do you know about electrochemical series?***

Ans. ***Definition:*** The list of elements arranged in the order of their standard electrode potentials on the hydrogen scale is called electrochemical series.

Standard reduction potential (E°) of elements at 298 K:

Element		*Electrode*				*Standard reduction potetial*
Li	↓ *Increasing strength as an oxidizing agent*	$Li^+ + e^-$	⟶	Li	↑ *Increasing strength as reducing agent*	-3.045
K		$K^+ + e^-$	⟶	K		-2.925
Ca		$Ca^{2+} + 2e^-$	⟶	Ca		-2.87
Na		$Na^+ + 2e^-$	⟶	Na		-2.717
Mg		$Mg^{2+} + 2e^-$	⟶	Mg		-2.37
Al		$Al^{3+} + 3e^-$	⟶	Al		-1.66
Zn		$Zn^{2+} + 2e^-$	⟶	Zn		-0.7628
Cr		$Cr^{3+} + 3e^-$	⟶	Cr		-0.74
Fe		$Fe^{2+} + 2e^-$	⟶	Fe		-0.44
Cd		$Cd^{2-} + 2e^-$	⟶	Cd		-0.403
Ni		$Ni^{2-} + 2e^-$	⟶	Ni		-0.25
Sn		$Sn^{2+} + 2e^-$	⟶	Sn		-0.14
Pb		$Pb^{2+} + 2e^-$	⟶	Pb		-0.126
H_2		$2H^+ + 2e^-$	⟶	H2		0.000
Cu		$Cu^{2-} + 2e^-$	⟶	Cu		+0.337
Cu		$Cu^+ + e^-$	⟶	Cu		+0.521

I_2		I_2	+ $2e^-$	⟶	$2I^-$	+0.535
Fe		Fe^{3+}	+ e^-	⟶	Fe^{2+}	+0.771
Ag		Ag^+	+ e^-	⟶	Ag	+0.7994
Hg		Hg^{2+}	+ $2e^-$	⟶	Hg	+0.885
Br_2		Br_2	+ $2e^-$	⟶	$2Br^-$	+1.08
Cl_2		Cl_2	+ $2e^-$	⟶	$2Cl^-$	+1.360
Au		Au^{3+}	+ $3e^-$	⟶	Au	+1.50
F_2		F_2	+ $2e^-$	⟶	$2F^-$	2.87

Q.22 ***Write a detailed note on applications of electrochemical series. OR What do you infer the electrochemical series (ECS) ?***

Ans. ***(i)*** ***Prediction of the feasibility of a chemical reaction:***
The electrochemical series helps to predict whether the reaction will take place or not. If sum of the reduction potential and oxidation potential of two elements (or two half cell reaction) is positive then the reaction will proceed otherwise not.

(ii) ***Calculation of voltage or electromotive force (emf) of cells:***
The electrochemical series helps to calculate the cell voltage of galvanic cell. The voltage i.e., emf of galvanic cell is the sum of the reduction potential of the cathode and oxidation potential of anode.

(iii) In the ECS there is decreasing tendency from top to bottom to lose electrons (oxidation) and increasing tendency to gain electrons (reduction).

(iv) ***Relative chemical reactivities of metals:***
The reactivity of metals having lower reduction potential is higher than those having greater reduction potential. The chemical reactivity of metals increases from bottom to top with the decrease in reduction potential.

(v) In ECS the metals are placed in the order of reactivity and shows the displacement order. Metals displace metals lying below them in the list from solution of their salts.

(vi) ***Strength as oxidizer or reducing agent:***
The electrochemical series helps to compare the strength of oxidizing agent or reducing agent.

Q.23 ***Define oxidation state and describe the rules for assigning oxidation number.***

Ans. ***Definition:*** The apparent charge, positive, negative, or zero, which an atom would have in a molecule or in an ion is called oxidation state or oxidation number.

Rules for assigning oxidation number:

(1) The oxidation number of a free element is zero e.g., oxidation number of Zn, Mg, O_2, H_2 and Cl_2 is zero.

(2) The oxidation number of hydrogen is +1 in its compounds except in metal hydrides where it is -1.

(3) The oxidation number of oxygen is -2 in its compounds except in peroxide such as H_2O_2 where it is -1. Another exception is the case of OF_2 in which the oxidation no. of oxygen is +2.

(4) The oxidation number of each element of group VII A (halogens) in binary compounds is -1. e.g., Cl in HCl has -1 oxidation number.

(5) The oxidation number of each element of group IA, IIA and IIIA are +1, +2 and +3 respectively.

(6) The oxidation number of a molecule or ion is the sum of the oxidation number of the constituent atoms.

(7) The oxidation number of a compound is zero whereas the oxidation number of an ion is equal to the charge on it.

(8) In any substance the more electronegative atom has negative oxidation number, where as less electronegative atom has positive oxidation number.

Q.24 ***Define the processes of oxidation and reduction.***

Ans. ***Oxidation:***

Oxidation is a chemical process in which electrons are lost by an atom or ion.

e.g:

Atom: $Na^{o} \longrightarrow Na^{+} + e^{-}$

Ion $Fe^{2+} \longrightarrow Fe^{3+} + e^{-}$

It is a process in which oxidation number of an element is increased.

(i) Addition of oxygen is called oxidation.
(ii) Removal of hydrogen is called oxidation.
(iii) Increase in positive charge is oxidation.
(iv) Decrease in negative charge is oxidation.

Reduction:

It is a chemical process in which electrons are gained by an element or ion.

e.g. $Cl_2 + 2e^{-} \longrightarrow 2Cl^{-}$

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

Reduction is process in which:

(i) oxidation number of an element is decreased.
(ii) addition of hydrogen is done.
(iii) removal of oxygen is done.
(iv) increase in negative charge happens.
(v) positive charge decreases.

Q.25 ***Explain oxidizing agent and reducing agent.***

Ans. ***Oxidizing Agent:***

An element or compound or ion which accepts electrons and shows decrease in oxidation number is called oxidizing agent. An oxidizing agent is an electron deficient species and always gains electrons therefore it is reduced.

e.g. $2K^{0} + Br_2 \longrightarrow 2K^{+}Br^{-}$

Bromine atom gains one electron from potassium atom and has -1 charge. It acts as an oxidizing agent.

Examples: F_2, Cl_2, O_2, H_2SO_4, HNO_3, $KMnO_4$

Reducing Agent: Substances that donate electrons and shows an increase in oxidation number is called reducing agent. It is always rich in electrons therefore it loses electrons and hence oxidized itself.

e.g. $Zn^{0} + Cl_2 \longrightarrow Zn^{2+}Cl_2^{-}$

Zn atom has lost $2e^{-}$, so it acts as a reducing agent

Examples: H_2, Na, Al, Cu, H_2S, KI, C.

Q.26 ***What is a redox reaction?*** ***Karachi Board: 2010***

Ans. Chemical reaction in which oxidation and reduction occur simultaneously are called redox reaction.

e.g. $Cu^{+2}O^{-2} + H_2 \longrightarrow Cu^0 + H_2O^0$

Reduced (Cu: +2 → 0)

Oxidized (H_2: 0 → +1)

Q.27 ***Write down the rules for balancing of redox equation by ion electron method.***

Ans. The key to balance redox equations is the electron transfer. The number of electrons lost by the reducing agent must be equal to the number of electrons gained by the oxidizing agent.
The following are the steps to balance a redox equation :

- ***Step 1:*** Assign the oxidation number to all the atoms involved in the equation.

$$H^{+1}Cl^{-1} + K_2^{+1}Cr_2^{+6}O_7^{-2} \longrightarrow K^{+1}Cl^{-1} + Cr^{+3}Cl_3^{-1} + Cl_2^0 + H_2^{+1}O^{-2}$$

- ***Step 2:***
  - (i) Select the atoms which change their oxidation number.
  - (ii) Calculate the number of electrons lost and gained per atom.
  - (iii) If the number of atoms, which change their oxidation number, is not equal on both sides, then make them equal by inserting temporary coefficient.
  - (iv) Calculate the total number of electrons lost and gained per formula unit.

(i) $HCl^{-1} + K_2Cr_2^{+6}O_7 \longrightarrow KCl + Cr^{+3}Cl_3 + Cl_2^0 + H_2O$

$1e^-$ lost per atom; $3e^-$ gained per atom

(ii) $2HCl^{-1} + K_2Cr_2^{+6}O_7 \longrightarrow KCl + 2Cr^{+3}Cl_3 + Cl_2^0 + H_2O$

$2e^-$ lost; $6e^-$ gained

- ***Step 3:*** Equalize the number of electrons lost and gained. To do so:
  - (i) Multiply the coefficient of the substances involved in oxidation by proper whole numbers.
  - (ii) Multiply the coefficient of the substance involved in reduction by proper whole numbers.

$6HCl^{-1} + K_2Cr_2^{+6}O_7 \longrightarrow KCl + 2Cr^{+3}Cl_3 + 3Cl_2^0 + H_2O$

$3 \times 2e^-$ lost; $(1) \times 6e^-$ gained

- ***Step 4:*** Proceed in the following order:
  - (i) Balance the atoms other than oxygen and hydrogen.
  - (ii) Balance the atoms of oxygen.
  - (iii) Balance the atoms of hydrogen.
    - (a) Balance K by multiplying the coefficient of KCl by 2 and then balance Cl by changing the coefficient of HCl by 14.

$$14HCl + K_2Cr_2O_7 \longrightarrow 2KCl + 2CrCl_3 + 3Cl_2 + H_2O$$

(b) Balance the atoms of oxygen, multiply the coefficient of H_2O by 7.

$$14HCl + K_2Cr_2O_7 \longrightarrow 2KCl + 2CrCl_3 + 3Cl_2 + 7H_2O$$

Inspect the equation, it has been balanced.

Q.28 ***Define indicator. Give the types and choice of an indicator.***

Ans. ***Indicators:*** They are complex organic compounds. They change their colour in acidic and basic medium. Indicators are used to determine the end point in titration. A large number of indicators are known and each undergoes a colour change when a certain pH is reached.

Colours of some indicators in different medium:

Indicator	*Colour in acid*	*Colour in base*	*Colour when neutral*
Phenolphthalein	Colourless	Pink	Colourless
Methyl orange	Red	Yellow	Orange
Litmus	Red	Blue	Purple
Universal indicator	Red	Purple	Green

- ***Choice of an indicator:***

The choice of suitable indicator for a particular acid - base titration depends upon the nature of the acid and the base involved in that titration. The different indicators which are used for different types of titrations are:

(a) for strong acids and strong bases any indicator can be used.
(b) for weak acid and strong base, phenolphthalein is used.
(c) for strong acids and weak base, methyl orange is used.

Q.29 ***Describe the strength of acids and bases.***

Ans. The extent of ionization of acids and bases are not the same. Some ionizes to a greater extent and some to a lesser extent. The extent of ionization is expressed in terms of degree of dissociation or percentage dissociation. Degree of dissociation is the ratio of the number of molecules ionized to the number of molecules dissolved.

$$\alpha = \frac{\text{No. of molecules ionized}}{\text{Total no. of molecules dissolved}}$$

The ratio when multiplied by 100 gives percentage dissociation i.e.,

$$\%\text{ age dissociation} = \frac{\text{No. of molecules ionized}}{\text{Total no. of molecules dissolved}} \times 100$$

Q.30 ***Describe strength of acid in the light of Bronsted-Lowry theory.*** ***Karachi Board: 2008***

Ans. According to Bronsted - Lowry theory:

Acids are proton (H+) donors and bases are proton acceptors.

$$\underset{(Acid)}{HA_{(aq)}} + \underset{(Base)}{H_2O_{(l)}} \longrightarrow H_3O^+_{(aq)} + A^-_{(aq)}$$

Applying the law of mass action:

$$K_c = \frac{[H_3O^+][A^-]}{[HA][H_2O]}$$

or

$$\frac{[H_3O^+][A^-]}{[HA]} = K_c [H_2O] = K_a$$

or

$$\frac{[H_3O^+][A^-]}{[HA]} = K_a \quad \text{(acid dissociation constant)}$$

The acid which has greater K_a value is stronger acid then those which have lower value of Ka.

e.g.,

Hydrocyanic acid	4.8×10^{-10}	K_a (mol. dm^{-3}) at 298 K
Formic acid	1.8×10^{-4}	K_a (mol. dm^{-3}) at 298 K
Acetic acid	1.8×10^{-5}	K_a (mol. dm^{-3}) at 298 K
Chloroacetic acid	1.4×10^{-3}	K_a (mol. dm^{-3}) at 298 K

Thus the chloroacetic acid is stronger than formic acid which in turn is stronger than acetic acid.

Q.31 ***Describe strength of acids and bases using pH.***

Ans. We use pH scale to know the exact strength of an acid or a base. In terms of pH, acid with low pH values, such as HCl, HNO_3 and H_2SO_4 are strong acids. Similarly bases with high pH values such as KOH, NaOH are strong alkalis. These substances are strong electrolytes and are nearly completely ionized in aqueous solution. pH of some acids / bases are given below:

pH of HCl	1.0	pH of Na_2CO_3	11.6
pH of H_2SO_4	1.2	pH of NaOH	13.0
pH of CH_3COOH	2.9		

Q.32 ***Define pH and pOH. What is the mathematical relationship between pH and pOH of an aqueous solution ?*** ***Karachi Board: 2007, 2008, 2010, 2015, 2017***

Ans. ***Definition of pH :*** The term pH was introduced by Sorenson in 1909.
The negative logarithm of the concentration of H^+ ions present in the solution in called pH of the solution.

$$pH = -\log [H^+]$$

pH of neutral water:

In neutral water $[H^+] = 1.0 \times 10^{-7}$ mol dm^{-3}

$$pH = -\log [H^+] = -\log [1.0 \times 10^{-7}] = 7$$

pH of neutral solution = 7
pH of acidic solution < 7
pH of basic solution > 7

- ***Definition of pOH :*** The negative logarithm of the concentration of OH ions present in the solution is called pOH of the solution:

Mathematical form:

$$pOH = - \log [OH^-]$$

pOH of neutral water:

In neutral water $[OH^-] = 1.0 \times 10^{-7}$ mol dm^{-3}

$pOH = - \log [OH^-] = \log [1.0 \times 10^{-7}] = 7$

Note:

pOH of neutral solution = 7
pOH of basic solution < or = 7
pOH of acidic solution > or = 7

Q.33 ***Describe the determination of pH of solution.*** *Karachi Board: 2012*

Ans. ***Determination of pH of a solution:***

pH of a solution can be measured by the following methods :

(a) By digital pH meter:

Now a days a pH meter having a glass electrode is used to determines the pH of a solution. This glass electrode when dipped into the solution shows the reading of the pH value on the meter.

[H+]	10^{0}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}
pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

← Acidic → Neutral ← Basic →

(b) By using universal indicator:

Universal indicator is formed by mixing together different indicators. Universal indicators indicates different colours of solution at different pH values which is givens as under:

Colours	Red	Orange	Yellow	Green	Blue	Deed Blue	Purple
pH	0	3	6	7	8	10	14

Q.34 ***Write down approximate pH of some common materials at 25°C.***

Ans.

Material	*pH*	*Material*	*pH*
1.0 M HCl	0.1	Bread	5.5
0.1 M HCl	1.1	Potatoes	5.8
1.0 M CH_3COOH	2.9	Rain water	6.2
Gastric juice	2.0	Milk	6.5
Lemon	2.3	Saliva	6.5 - 6.9
Vinegar	2.8	Pure water	7.0
0.1 M $NaHCO_3$	8.4	Eggs	7.8
Soft drinks	3.0	Apples	3.1

Cherries	3.6	Sea water	8.5
Tomatoes	4.2	Milk of magnesia	10.5
Bananas	4.6	0.1 M NH_3	11.1
Grapefruit	3.1	0.05 M Na_2CO_3	11.6
Oranges	3.5	0.1 m NaOH	13.0

Q.35 ***Define buffer solution and write down its preparation.*** *Karachi Board: 2005, 2007, 2010, 2011*

Ans. ***Buffer solution:*** The solutions which resist the change in their pH, when a small amount of acid or a base is added to them are called buffer solutions.

PH of a buffer solution remains constant and does not change even on dilution and keeping for long time.

Preparation of buffer solution of pH lesser than 7 (Acidic buffer solution):

Such solution can be prepared by mixing weak acids and their salts with strong bases. Mixture of acetic acid and sodium acetate is an example of such buffer solution:

$$CH_3COOH + CH_3COO^-Na^+_{(aq)} = \text{Buffer solutions}$$

Preparation of buffer solution of pH greater than 7 (Basic buffer solution):

Such solution can be prepared by mixing weak bases and their salts with strong acid. Mixture of ammonium hydroxide and ammonium chloride is an example of such buffer solution.

$$NH_4OH_{(aq)} + NH_4^+ + Cl^-_{(aq)} = \text{Buffer solutions}$$

Q.36 ***Write down the needs / properties of buffer solution.*** *Karachi Board: 2010*

Ans. ***Need for buffer solution:***

(1) The pH of the human blood is maintained at 7.35. A person may die if pH of his blood change to 7.00 or 8.00

(2) Buffers are important in many areas of chemistry and allied sciences like molecular biology, microbiology, cell biology, soil sciences, nutrition and clinical analyses.

(3) Many inorganic and organic reactions are performed in laboratory use buffer solution to minimize any adverse effect caused by acids or bases that might be consumed or produced during reaction.

Q.37 ***How do the buffer act ?***

Ans. ***Action of buffer:*** Buffer of different pH can be prepared by changing the concentration of CH_3COONa and CH_3COOH.

To prepare a buffer solution mix CH_3COOH and CH_3COONa, both will dissociate a follows:

$$CH_3COOH \xrightleftharpoons{H_2O} CH_3COO^-_{(aq)} + H^+_{(aq)} \quad \text{(i)}$$

$$CH_3COONa \xrightleftharpoons{H_2O} CH_3COO^-_{(aq)} + Na^+_{(aq)} \quad \text{(ii)}$$

Presence of CH_3COONa in the solution causes to increase the concentration of CH_3COO^- on (common ion), which shift the equilibrium of equation (i) towards the backward direction. This decreases the ionization of CH_3COOH. Addition of more and more CH_3COONa decreases the ionization of CH_3COOH which causes to increase the pH of buffer.

Addition of a strong acid / base to the buffer does not change the pH significantly.

(i) When a strong acid such as HCl is added to the buffer, following reaction takes place:

$$CH_3COONa + HCl \rightleftharpoons CH_3COOH + NaCl$$

According to above equation, NaCl being neutral and CH_3COOH being weak acid do not change pH significantly.

(ii) When a strong base such as NaOH is added to the buffer following reaction takes place.

$$CH_3COOH + NaOH \rightleftharpoons CH_3COONa + H_2O$$

H_2O being neutral and CH_3COONa being weak basic salt do not change pH significantly.

Q.38 ***What is neutralization ? Give the example of normal, acidic and basic salts.***

Karachi Board: 2011

Ans.

Neutralization: The reaction of an acid with a base is called neutralization. As a result salt and water are formed.

$$\text{Acid} + \text{Base} \rightleftharpoons \text{Salt} + \text{Water}$$

$$HCl + NaOH \rightleftharpoons NaCl + H_2O$$

In the above reaction H^+ ion of the acid combines OH^- ions of the base to form water.

Types of neutralization:

(i) Complete neutralization

(ii) Partial neutralization

(i) Complete neutralization: In this type, an acid completely neutralize the base. As a result neutral salt is produced.

$$NaOH_{(aq)} + HCl_{(aq)} \rightleftharpoons NaCl_{(aq)} + H_2O$$

(ii) Partial neutralization: Neutralization reaction in which an acid partially neutralize a base or a bass incompletely neutralize an acid is termed as partial neutralization reaction as a result acidic or basic salts are formed. For example:

$$H_2SO_4 + NaOH \rightleftharpoons NaHSO_4 + H_2O$$

(Acidic salt)

$$HCl + Mg(OH)_2 \rightleftharpoons Mg(OH)_2Cl + H_2O$$

(Basic salt)

Solved Problems of Textbook

Oxidation Number

Example 1: ***Give the oxidation number of tin in $SnCl_2$ and $SnCl_4$.***

Solution:

Since oxidation number of each chlorine atom is -1, hence total negative charge in $SnCl_2$ is -2. To balance the negative and positive oxidation number, the oxidation number of Sn must be +2.

O.N. of Sn in $Sn^{+2}Cl_2^{-1}$ = +2

Similarly in $SnCl_4$ the O.N. of Sn = +4

O.N. of Sn in $Sn^{+4}Cl_4^{-1}$ = +4

Example 2: ***Give the oxidation number of Nitrogen in HNO_3.***

Solution:

In HNO_3 the O.N. of oxygen is -2 since hydrogen is +1 therefore O.N. of nitrogen is +5.

O.N. of N in $H^{+1}N^{+5}O_3^{-2}$ = +5

Example 3: ***Determine the oxidation number of S in SO_3^{2-}.***

Solution:

The total oxidation number of three oxygen atoms is -6. -2 is be left as the charge on the whole ion, therefore, the oxidation number of sulphur is +4.

O.N. of S = $[S^{+4}O_3^{(-2)3}]^{-2}$

Example 4: ***Balance the oxidation of H_2S with HNO_3 by ion electron method.***

Solution:

Step 1: ***Write the skeleton equation:***

$$HNO_3 + H_2S \longrightarrow NO + S + H_2O$$

Step 2: ***Transform molecular equation into ionic form:***

$$NO_3^- + H_2S \longrightarrow NO + S$$

The oxidizing agent is the nitrate ion NO_3^- (Undergoes decrease in oxidation state).

The reducing agent is H_2S (since sulphur undergoes increase in oxidation state).

Step 3: ***Split the ionic equation into two partial equations (oxidation reduction):***

$N^{+5}O_3^- \longrightarrow N^{+2}O^{-2}$ (reduction of N from +5 to +2)

$H_2S^{-2} \longrightarrow S^0$ (oxidation of S from -2 to 0)

Step 4: ***Balance the partial equations. Since medium is acidic, oxygen and hydrogen atoms are balanced by adding H_2O and H^+:***

In the first partial equation, $2H_2O$ must be added to the right side to balance the oxygen atoms. Then $4H^+$ are added to the left to balance hydrogen.

$$NO_3^- + 4H^+ \longrightarrow NO + 2H_2O$$

In the second partial equation, $2H^+$ are added to the right side to balance two hydrogen atoms on the left.

$$H_2S \longrightarrow S + 2H^+$$

Step 5: ***Charge is balanced in the partial equation by adding electrons. The first equation, the net charges on the left is 4+ (1-) = 3+ and on the right is zero. Hence 3 electrons are added to the left side.***

$$NO_3^- + 4H^+ + 3e^- \longrightarrow NO + 2H_2O$$

In the second equation, the net charge on the right is 2^+, 2 electrons are added to make it zero as on the left.

$$H_2S \longrightarrow S + 2H^+ + 2e^-$$

Step 6: ***In order to equate the electron lost and gained, the first partial equation is multiplied by 2 and the second by 3 (cross multiplied).***

$$2NO_3^- + 8H^+ + 6e^- \longrightarrow 2NO + 4H_2O$$
$$3H_2S \longrightarrow 3S + 6H^+ + 6e^-$$

Step 7: ***Cancel out the electrons and add the partial equations:***

$$2NO_3^- + 3H_2S + 8H^+ \longrightarrow 2NO + 3S + 4H_2O + 6H^+$$

Since $6H^+$ are common to both side hence they are cancelled.

$$2NO_3^- + 3H_2S + 2H^+ \longrightarrow 2NO + 3S + 4H_2O \quad \text{(Balanced)}$$

This equation may be corrected back to molecular form:

$$2HNO_3 + 3H_2S \longrightarrow 2NO + 3S + 4H_2O$$

Example 5: ***The oxidation of $FeSO_4$ by $KMnO_4$ in acidic solution.***

Solution:

Step 1: ***The skeleton equation:***

$$KMnO_4 + H_2SO_4 + FeSO_4 \longrightarrow MnSO_4 + Fe_2(SO_4)_3 + K_2SO_4 + H_2O$$

Step 2: ***Transform into ionic form:***

$$MnO_4^- + Fe^{+2} \longrightarrow Mn^{2+} + Fe^{3+}$$

Step 3: ***Make partial equation:***

$$Mn_4^- \longrightarrow Mn^{2+}$$
$$Fe^{2+} \longrightarrow Fe^{3+}$$

Step 4: ***Balance the equation:***

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

Step 5: ***Balance the charge by adding electrons:***

$$MnO^{4-} + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$
$$Fe^{2+} \longrightarrow Fe^{3+} + 1e^-$$

Step 6: ***To equate the electrons lost and gained, multiply the second equation by 5:***

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

Step 7: ***After cancelling electrons, add the two partial equations:***

$$MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O \quad \text{(Balanced)}$$

To convert back to the molecular form:

$$2KMnO_4 + 10FeSO_4 + 8H_2SO_4 \longrightarrow 2MnSO_4 + 5Fe_2(SO_4)_3 + K_2SO_4 + 8H_2O$$

pH

Example 6: ***What is pH of 0.004 mol dm^{-3} HCl (fully dissociated) at 25°C ?***

Solution:

The fully dissociated HCl has $[H^+] = 4.0 \times 10^{-3}$ mole dm^{-3}, so

$pH = -\log (4.0 \times 10^{-3}) = (-\log 4.0) + (-\log 10^{-3}) = 0.06 + 3 = 2.40$

$pH = 2.40$ **Ans.**

Example 7: ***The pH of a solution is 9.63. Compute its hydrogen ion concentration.***

Solution:

The pure exponential number is $10^{-9.63}$ converting this number to a mixed number, we have

$10^{-9.63} = 10^{0.63} \times 10^{-9} = 10^{0.37} \times 10^{-10}$

$[H^+] = 2.34 \times 10^{-10}$

Therefore, the concentration of hydrogen ion in this solution is 2.34×10^{-10} mol dm^{-3}.

Solved Problems From Past Papers

Problem 1: ***Calculate the molarity of the solution prepared by dissolving 4.5 gm of NaOH is 500cm of water.***

Solution: ***Karachi Board: 2014***

Mass = 4.5 gm Volume = 500 cm^3 or 0.5 dm^3

Molarity = ? No. of moles = ?

Molecular mass of NaOH = 23 + 16 + 1 = 40

$$\text{No. of moles} = \frac{\text{Mass in gm}}{\text{Molecular Mass}} = \frac{4.5}{40} = 0.1125 \text{ moles}$$

$$\text{Molarity} = \frac{\text{No. of moles}}{\text{Volume is dm}^3} = \frac{0.1125}{0.5} = 0.225$$

Molarity of NaOH is 0.225 mol/dm^3 **Ans.**

Problem 2: ***3.86 gram of NaOH is dissolved in 2.5 dm^3 of solution find its molarity.***

Solution: ***Karachi Board: 2013***

Mass of NaOH = 3.86 gm

Volume of solution = 2.5 dm^3

Molarity = ?

Molecular mass of NaOH = 40

$$\text{Molarity} = \frac{\text{Mass of solute}}{\text{Molar Mass} \times \text{Volume of solution}}$$

$$\text{Molarity} = \frac{3.86}{40 \times 2.25} = 0.0386$$

Molarity = 0.0386 **Ans.**

Problem 3: ***Which one is more concentrated 1 M NaOH or 1 molal NaOH aqueous solution? Explain it.***

Solution: ***Karachi Board: 2008***

1 molar NaOH solution means 40gm of NaOH in 1 litre of solution.
1 molal NaOH solution means 40gm of NaOH in 1kg of solution.

The concentration of both solution is the same.

Problem 4: ***Find the molarity of 0.5gm of NaOH in 250 cm^3 of aqueous solution.***

Solution: ***Karachi Board: 2007***

Mass of NaOH = 0.5gm
Volume of solution = 250 cm^3 or 0.25 dm^3
Molecular mass of NaOH = 40
Molarity = ?

Formula: $$\text{Molarity} = \frac{\text{Given mass}}{\text{Molecular Mass} \times \text{Volume in } dm^3}$$

$$M = \frac{0.5}{40 \times 0.25}$$

$$M = \frac{-0.5}{10} = 0.05$$

Molarity = 0.05 mol / dm^3 **Ans.**

Problem 5: ***Determine the weight of a solute required to prepare 5dm^3 of 1.2 M NaOH solution.***

Solution: ***Karachi Board: 2006***

Mass of NaOH = ?
Volume of NaOH solution = 5 dm^3
Molarity = 1.2 M

Formula: $$M = \frac{\text{no. of moles}}{\text{Volume in } dm^3}$$

$$M = \frac{\text{Mass in gms}}{\text{Molecular mass} \times \text{Volume in } l}$$

$$1.2 = \frac{\text{Mass in gms}}{40 \times 5}$$

$$1.2 = \frac{\text{Mass in gms}}{200}$$

$$\text{Mass} = 1.2 \times 200$$

$$\text{Mass of NaOH} = 240 \text{ gms}$$ **Ans.**

Problem 6: ***A 500 cm^3 solution is prepared by dissolving 1.26 gm of HNO_3 in H_2O calculate the molarity.***

Solution: ***Karachi Board: 2004***

Volume = 500 cm^3 = 0.5 dm^3 Mass = 1.26 gm

Mol. Mass of HNO = 63 gm Molarity = ?

Formula: $$M = \frac{\text{Mass in gms}}{\text{Mol. Mass} \times \text{Volume in dm}^3}$$

$$M = \frac{1.26}{63 \times 0.5} = 0.04$$

$$M = 0.04 \text{ moles/dm}^3$$ **Ans.**

Problem 7: ***19.6 gm of H_2SO_4 is dissolved in 500 cm^3 water to make solution. What mass of NaOH should be dissolved in 250 cm^3 of water to prepare the solution of the same molarity as that of H_2SO_4.***

Solution: ***Karachi Board: 2017***

Mass of H_2SO_4 = 19.6 gm

Mole of H_2SO_4 $= \frac{19.6}{98} = 0.2$ mol

Volume of H_2SO_4 = 500 cm^3 $= \frac{500}{1000} = 0.5$ dm^3

Molarity $= \frac{0.2}{0.5} = 0.4$ mol/dm^3

$$\text{Amount of NaOH} = \frac{\text{Molarity} \times \text{Molecular mass} \times \text{Volume}}{1000}$$

$$= \frac{0.4 \times 40 \times 250}{1000}$$

Mass of NaOH = 4 gm **Ans.**

Problems of pH

Problem 8: *pH of a solution is 8.4. Calculate the H^+ ion and OH^- ion concentration.*

Solution: *Karachi Board: 2013*

pH = 8.4 $[H^+]$ = ? $[OH^-]$ = ?

We know that:

$pH = -\log [H^+]$

$8.4 = -\log [H^+]$

Multiplying by -1 on both sides:

$-8.4 = \log [H^+]$

Taking antilog on both sides:

$\text{antilog}(-84) = [H^+]$

$[H^+] = 3.98 \times 10^{-9}$ M

Now for $[OH^-]$

$pH + pOH = 14$

$8.4 + pOH = 14$

$pOH = 14 - 8.4$

$pOH = 5.6$

$pOH = -\log [OH^-]$

$5.6 = -\log [OH^-]$

Multiply by -1 on both sides:

$-5.6 = \log [OH^-]$

Taking antilog on both sides:

$\text{antilog}(-5.6) = [OH^-]$

Result: $[OH^-] = 2.5118 \times 10^{-6}$ M

Problem 9: *10 gm H_2SO_4 has been dissolved in excess of water to dissociate it completely into ions. Calculate the:*

(i) Number of molecules in 10 gm of H_2SO_4

(ii) Number of positive ions.

Solution: *Karachi Board: 2016*

Mass = 10 gm

Molecular mass of $H_2SO_4 = 1 \times 2 + 32 - 16 \times 4 = 2 + 32 + 64 = 98$ a.m.u.

No. of molecules = ?

No. of positive ions = ?

We know that:

$$\text{No. of molecules} = \frac{\text{Mass in gm} \times N_A}{\text{Molecular Mass}}$$

$$\text{No. of molecules} = \frac{(10)\ (6.02 \times 10^{23})}{98}$$

No. of molecules = 6.14×10^{22} molecules **Ans.**

No. of positive ions = $2 \times 6.14 \times 10^{22}$

No. of positive ions = 12.28×10^{22} ions **Ans.**

Problem 10: ***Find the pH of 0.004 mol / dm³ of HCl (fully dissociated) at 25C°.***

Solution: ***Karachi Board: 2005, 2011***

$[H^+] = 4.0 \times 10^{-3}$ mol / dm³

$pH = -\log [H^+] = -\log [4.0 \times 10^{-3}] = (-\log 4.0) + (-\log 10^{-3}) = -0.60 + 3$

$pH = 2.40$ **Ans.**

Problem 11: ***What is the H^+ and OH^- ion concentration of a solution having pH equals to 7.86 ?***

Solution: ***Karachi Board: 2010***

$pH = 7.86$ $[H^+] = ?$ $[OH^-] = ?$

For calculating [H^+]:

$pH = -\log [H^+]$

$7.86 = -\log [H^+]$

$[H^+] =$ antilog (-7.86)

$[H^+] = 1.3 \times 10^{-8}$ mol / dm³

For calculating [pOH]:

$pH + pOH = 14$

$pOH = 14 - 7.86$

$pOH = 6.14$

$pOH = -\log [OH^-]$

$6.14 = -\log [OH^-]$

$[OH^-] =$ antilog 6.14

$[OH^-] = 7.24 \times 10^{-7}$ mol / dm³

Problem 12: ***Calculate pH of 4.6×10^{-3} M solution of HCl.***

Solution: ***Karachi Board: 2006***

$pH = ?$ $[H^+] = 4.6 \times 10^{-3}$ M

Formula: $pH = -\log [H^+]$

$pH = -\log [4.6 \times 10^{-3}]$

$pH = -(-2.33)$

$pH = 2.33$ **Ans.**

Problem 13: *What is the pH of 0.002 M NaOH solution at 25°C ?*

Solution: ***Karachi Board: 2015***

Data:

$$[OH] = 0.002\ M$$

$$pH = ?$$

$$pOH = -\log [OH] = -\log (0.002) = 2.70$$

As we know that:

$$pH + pOH = 14$$

$$pH = 14 - pOH = 14 - 2.70$$

$$pH = 11.3$$ **Ans.**

Problem 14: *The aqueous solution of 0.3 M $Mg(OH)_2$ is 60% ionized. Calculate its pH.*

Solution: ***Karachi Board: 2016***

Percentage dissociation = 60%

Molecular mass of $Mg(OH)_2$ = 24 + 2 (17) = 58 a.m.u.

Molarity = 0.3 M

$$[OH^-] = \frac{(0.3)\ (60)}{100} = 0.18\ M$$

$$pOH = -\log [OH^-] = -\log [0.18]$$

$$pOH = 0.744$$

$$pH = 14 - pOH = 14 - 0.744$$

$$pH = 13.256$$

Problem 15: *Calculate the pH & pOH of a solution of Nitric acid whose concentration is $2.0 \times 10\text{-}2$ mole / dm^3 .*

Solution: ***Karachi Board: 2017***

$$pH = -\log [H^+]$$

$$pH = -\log [2.0 \times 10^{-2}]$$

$$pH = 1.70$$ **Ans.**

$$pOH = 14 - pH$$

$$pOH = 14 - 1.7$$

$$pOH = 12.3$$ **Ans.**

Problems on Oxidation Number

Problem 16: ***Find the oxidation number of :***

(i) Mn in MnO_4^- ***(ii) N in NCl_3***

(iii) Fe in $Fe_2(SO_4)_3$ ***(iv) P in H_3PO_4***

Karachi Board: 2005, 2011, 2013

Solution:

(i) **Mn in MnO_4^-**

Let x = Mn
Mn + O_4 = -1
x + (-2 × 4) = -1
x - 8 = -1
x = -1 + 8
x = +7
Mn = +7 **Ans.**

(ii) **N in NCl_3**

Let x = N
x + Cl_3 = 0
x + (-1 × 3) = 0
x - 3 = 0
x = +3
N = +3 **Ans.**

(iii) **Fe in $Fe_2(SO_4)_3$**

Let Fe = x
Fe_2 = 2x
2x + (-2 × 3) = 0
2x = 6
x = 3
Fe = +3 **Ans.**

(iv) **P in H_3PO_4**

Let P = x
H_3 + x + O_4 = 0
(+1 × 3) + x + (-2 × 4) = 0
+3 + x + (-8) = 0
x - 5 = 0
x = +5
P = +5 **Ans.**

Problem 17: ***Find the oxidation number of :***

(i) Cr in $K_2Cr_2O_7$ ***(ii) S in $Na_2S_2O_3$***

Karachi Board: 2005, 2006,. 2011

Solution:

(i) **Cr in $K_2Cr_2O_7$**

2(K) + 2(Cr) + 7(O) = 0
2(1) + 2(Cr) + 7(-2) = 0
2 + 2Cr - 14 = 0
2Cr = 14 - 2 = 0
Cr = 12 / 2
Cr = + 6 **Ans.**

(ii) **S in $Na_2S_2O_3$**

2(Na) + 2(S) + 3(O) = 0
2(1) + 2(S) + 3(-2) = 0
2 + 2S - 6 = 0
2S = 6 - 2
2S = 4
S = 4 / 2
S = +2 **Ans.**

Problem 18: ***Find the oxidation number of O in OF_2 and H in H_2.***

Karachi Board: 2004, 2008, 2009

Solution:

Oxidation Number of O in OF_2 :

O + 2(F) = 0
O + 2(-1) = 0
O - 2 = 0
O = +2 **Ans.**

Oxidation Number of H in H_2 :

In free state oxidation number is zero.
2(H) = 0
H = 0

Problem 19: *Find the oxidation number of the following:*
(a) Cl in $Mg(ClO_4)_2$ *(b) P in $P_2O_7^{-4}$*

Solution: *Karachi Board: 2006*

(a)
$Mg + 2(Cl) + 8(O) = 0$
$(+2) + 2(Cl) + 8(-2) = 0$
$+2 + 2Cl - 16 = 0$
$2Cl = 16 - 2$
$2Cl = 14$
$Cl = 14/2$
$Cl = +7$ **Ans.**

(b)
$2P + 7(O) = -4$
$2P + 7(-2) = -4$
$2P - 14 = -4$
$2P = -4 + 14$
$2P = 10$
$P = 10/2$
$P = 5$ **Ans.**

Balancing of Chemical Equation

Problem 20: *Balance the following equations by ion electron method:*
(a) $Cl_2 + OH^- \longrightarrow Cl^- + ClO_3^- + H_2O$ *(Basic)*
(b) $Cr_2O_7^{-2} + I_2 \longrightarrow Cr^{3+} + IO_3^-$ *(Acidic)*

Solution: *Karachi Board: 2006, 2013*

(a) $Cl_2 + OH^- \longrightarrow Cl^- + ClO_3^- + H_2O$ **(Basic)**

Oxidation state:

$Cl_2 + OH^- \longrightarrow Cl^- + Cl^{+5}O_3^- + H_2^{+}O^{-2}$ _____ (i)

Reduction

$Cl_2 \longrightarrow 2Cl^-$ _____ (ii)

$Cl_2 + 2e^- \longrightarrow 2Cl^-$ _____ (iv)

$Cl_2^0 + 12OH^- - 10e^- \longrightarrow 2Cl^{+5}O_3^- + 6H_2O$

Oxidation:

$Cl_2^0 \longrightarrow 2Cl^{+5}O_3^-$ _____ (iii)

$Cl_2^0 + 12OH^- \longrightarrow 2Cl^{+5}O_3^- + H_2O$ _____ (v)

_____ (vi)

Multiply eq (iv) by 5 and eq (vi) by 1, we have:

$5Cl_2^0 + 10e^- \longrightarrow 10Cl^-$ _____ (vii)

$2Cl_2^0 + 12OH^- - 10e^- \longrightarrow 2Cl^{+5}O_3^- + 6H_2O$ _____ (viii)

By adding equations (vii) and (viii), we get:

$6Cl_2 + 12OH^- \longrightarrow 10Cl^- + 5Cl^{+5}O_3^- + 6H_2O$ (Balanced)

(b) $Cr_2O_7^{-2} + I_2 \longrightarrow Cr^{3+} + IO_3^-$ **(Acidic)**

$Cr_2O_7^{-2} \longrightarrow 2Cr^{+3}$

$Cr_2O_7^{-2} \longrightarrow 2Cr^{+3} + 7H_2O$

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

Multiply eq (i) by 5:

$5Cr_2O_7^{-2} + 7OH^+ + 30e^- \longrightarrow 10Cr^{+3} + 35H_2O$

$I_2 \longrightarrow IO_3^-$

$I_2 \longrightarrow 2IO_3^-$

$I_2 + 6H_2O \longrightarrow 2IO_3^-$

$I_2 + 6H_2O \longrightarrow 2IO_3^- + 12H^+$

$I_2 + 6H_2O \longrightarrow 2IO_3^- + 12H^+ + 10e^-$ ---(ii)

Multiply eq (ii) by 3:

$3I_2 + 18H_2O - 30e^- \longrightarrow 6IO_3^- + 36H^+$

Problem 21: (a) $Cr(OH)_3 + SO_4^{2-} \longrightarrow CrO_4^{2-} + SO_3^{2-}$ *(Basic medium)*
(b) $MnO_4^- + C_2O_4^{2-} \longrightarrow Mn^{2+} + CO_2$ *(Acidic medium)*

Solution: *Karachi Board: 2005, 2012*

(a) $Cr(OH)_3 + SO_4^{2-} \longrightarrow CrO_4^{2-} + SO_3^{2-}$ **(Basic medium)**

Karachi Board: 2019

Oxidation

$Cr(OH)_3 \longrightarrow CrO_4^{2-}$

$Cr(OH)_3 + 5OH^- \longrightarrow CrO_4^{2-} + 4H_2O + 3e^-$ -(1)

Reduction

$SO_4^{2-} \longrightarrow SO_3^{2-}$

$SO_4^{2-} + H_2O + 2e^- \longrightarrow SO_3^{2-} + 2OH^-$ -(2)

Multiply eq. 1 by 2 and eq. 2 by 3, we get:

$2Cr(OH)_3 + 10OH^- \longrightarrow 2CrO_4^- + 8H_2O + 6e^-$ -(3)

$3SO_4^{2-} + 3H_2O + 6e^- \longrightarrow 3SO_3^{2-} + 6OH^-$ -(4)

Add eq. 3 and 4:

$2Cr(OH)_3 + 10(OH^-) \longrightarrow 2CrO_4^- + 8H_2O + 6e^-$

$3SO_4^{2-} + 3H_2O + 6e^- \longrightarrow 3SO_3^{2-} + 6OH^-$

$2Cr(OH)_3 + 4(OH^-) + 3SO_4^{2-} \longrightarrow 2CrO_4^{-2} + 5H_2O + 3SO_3^{2-}$

(b) Reduction:

$MnO_4^- \longrightarrow Mn^{2+}$

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

$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$ _____ (1)

Oxidation:

$C_2O_4^{2-} \longrightarrow CO_2$

$C_2O_4^{2-} \longrightarrow 2CO_2$

$C_2O_4^{2-} \longrightarrow 2CO_2 + 2e^-$ _____ (2)

Multiplying equation (1) by 2 and equation (2) by 5:

$2MnO_4^- + 16H^+ + 10e^- \longrightarrow 2Mn^{2+} + 8H_2O$ _____ (3)

$5C_2O_4^{2-} \longrightarrow 10CO_2 + 10e^-$ _____ (4)

Now, add equation (3) and (4) of the above equations, we get:

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

$5C_2O_4^{2-} \longrightarrow 10CO_2 + 10e^-$

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

Problem 22: $MnO_4^{-1} + SO_3^{-2} \longrightarrow Mn^{2+} + SO_4^{-2}$ *(acidic medium)*

Solution: *Karachi Board: 2007, 2010, 2011, 2018*

Split the given equation into two half equation:

$MnO_4^- \longrightarrow Mn^{2+}$ (reduction +7 to +2)

$S^{+4}O_3^{-2} \longrightarrow SO_4^{-2}$ (oxidation from +4 to +6)

Balance the atoms of H and O:

$SO_3^{-2} + H_2O \longrightarrow SO_4^{-2} + 2H^+$

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

Balance the charge on both sides of equations:

$SO_3^{-2} + H_2O \longrightarrow SO_4^{-2} + 2H^+ + 2e^-$ _____ (i)

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

Multiply eq. (i) by 5 and eq. (ii) by 2:

$5SO_3^{-2} + 5H_2O \longrightarrow 5SO_4^{-2} + 10H^+ + 10e^-$

$2MnO_4^- + 10H^+ + 10e^- \longrightarrow 2Mn^{2+} + 8H_2O$

Add the above two equations:

$5SO_3^{-2} + 2MnO_4^- + 5H_2O + 16H^+ \longrightarrow 5SO_4^{-2} + 2Mn^{+2} + 10H^+ + 8H_2O$

Simplify the equation by subtracting H^+ and H_2O from both sides:

$5SO_3^{-2} + 2MnO_4^- + 6H^+ \longrightarrow 5SO_4^{-2} + 2Mn^{+2} + 3H_2O$

Now, the equation is balanced.

Problem 23: $MnO_4^- + Cl^- \longrightarrow Mn^{+2} + Cl_2$ *(Acidic medium)*

Solution: *Karachi Board: 2010-2012-2019*

Split the two equations :

$Mn^{+7}O_4^- \longrightarrow Mn^{+2}$ _____ (1) (reduction of Mn + 7 to + 2)

$2Cl^- \longrightarrow Cl_2^\circ$ _____ (2) (oxidation Cl -1 to 0)

Balancing the partial equations; since medium is acidic, oxygen and hydrogen atoms are balanced by adding H_2O and H^+:

$MnO_4^- + 8H^+ \longrightarrow Mn^{+2} + 4H_2O$ _____ (3)

$2Cl^- \longrightarrow Cl_2$ _____ (4)

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

$2Cl^- \longrightarrow 2e^- + Cl_2$ _____ (6)

Multiply eq. 5 by 2 and eq. 6 by 5, then add them to get:

$2MnO_4^- + 16H^+ + 10e^- \longrightarrow 2Mn^{+2} + 8H_2O$ _____ (7)

$10Cl^- \longrightarrow 10e^- + 5Cl_2$ _____ (8)

$2MnO_4^- + 16H^+ + 10Cl^- \longrightarrow 2Mn^{+2} + 8H_2O + 5Cl_2$ (Balanced)

Problem 24: $Fe^{+2} + MnO_4^- + H^+ \longrightarrow Fe^{3+} + 2Mn^{+2} + H_2O$

Solution: *Karachi Board: 2008, 2009*

$Fe^{+2} \longrightarrow Fe^{3+}$ $MnO_4^- \longrightarrow Mn^{+2}$

Balance partial equations:

$Fe^{+2} \longrightarrow Fe^{3+} + 1e^-$ (oxidation) _____ (1)

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

To balance number of electron, multiply eq. by 5:

$5Fe^{+2} \longrightarrow 5Fe^{3+} + 5e^-$ _____(3)

Now, add equations 2 and 3:

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

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

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

Problem 25: $Cr_2O_7^{-2} + I^- \longrightarrow Cr^{-3} + I_2$ *(acidic medium)*

Solution: *Karachi Board: 2007*

Reduction

$Cr_2O_7^{-2} \longrightarrow Cr^{+3}$

$Cr_2O_7^{-2} \longrightarrow 2Cr^{+3}$

$Cr_2O_7^{-2} \longrightarrow 2Cr^{+3} + 7H_2O$

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

$Cr_2O_7^{-2} + 14H^+ + 6e^- \longrightarrow 2Cr^{+3} + 7H_2O$ ___(1)

Oxidation

$I^- \longrightarrow I_2$

$2I^- \longrightarrow I_2$

$2I^- \longrightarrow I_2 + 2e^-$ _____(2)

Multiply eq. (2) by 3:

$(2I^- \longrightarrow I_2 + 2e^-) \times 3$

$6I^- \longrightarrow 3HI_2 + 6e^-$ _____(3)

Cancel out the electron and add eq. 1 and 3:

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

$6I^- \longrightarrow 3HI_2 + 6e^-$

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

Problem 26: ***Balance the following equation by ion-electron method:***

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

Solution: *Karachi Board: 2015*

Reduction

$Cr_2O_7^{-2} \longrightarrow Cr^{+3}$

$Cr_2O_7^{-2} \longrightarrow 2Cr^{+3} + 7H_2O$

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

Oxidation

$Fe^{+2} \longrightarrow Fe^{+3}$

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

Multiplying by 6:

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

Adding both parts:

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

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

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

Differences

Karachi Bourd: 2019

S. No.	*Hydration*	*Hydrolysis*
1.	The process in which water molecules surround the solute ions or molecules is called hydration.	The process in which an ionic solid reacts chemically with water producing H^+ or OH^- ions is called hydrolysis.
2.	There is no chemical reaction between the solute and H_2O molecules.	The reaction between solute ions and water molecules occurs, e.g., $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$
3.	In the crystalline state of an ionic salt there is a definite number of H_2O molecules as part of the crystal.	The solution of salt in water may be basic or acidic depending upon the extent of hydrolysis.
4.	Example : $CuSO_4 . 5H_2O$	Example: $NH_4Cl + H_2O \longrightarrow NH_4OH + HCl$

S. No.	*Electrochemical Cell*	*Electrolytic Cell*
1.	A device which converts chemical energy into electrical energy.	A device which converts electrical energy into chemical energy.
2.	It is based upon the redox reaction, which is spontaneous.	The redox reaction is non-spontaneous and takes place only when electrical energy is supplied.
3.	A salt bridge / porous pot is used	No salt bridge is used.
4.	The electrode on which oxidation takes place is called the anode and the electrode on which reduction takes place is called the cathode.	The electrode which is connected to the negative terminal of the battery is called cathode. The cations migrate to it and gains electrons. Here reduction takes place. The other electrode is called anode.
5.	Examples: torch cell, car battery etc.	NaCl solution given chemical H_2Cl_2 and NaOH.

S. No.	*Electrolytic Cell*	*Galvanic or Voltaic Cell*
1.	It is a device for converting electrical energy into chemical energy by passing current through an electrolyte. Chemical reaction take place.	A device for converting chemical energy into electric energy. Spontaneous redox reaction is used for the production of electric current.

2.	It consists of a vessel containing electrodes and it is a source of direct current (battery).	It consists of two half cells. Each half cell consists of an electrode and the solution of a salt.
3.	Example: electrolysis of aqueous solution of NaCl.	Example: Daniel cell $Zn/ZnSO_4$, $Cu/CuSO_4$

S. No.	*Oxidation Number*	*Valency*
1.	The apparent charge (+ve , - ve or zero) which an atom would have on a molecule or an ion is called oxidation state.	The combining capacity of an element with other element is called valency.
2.	It can be whole number and fractional.	It is always in whole number.
3.	It can be zero.	It can not be zero with exception of noble gases.
4.	Examples: Na^{+1}, $K^{+1}Mn^{+7}O_4^{-2}$	Examples: Na^{+1}, Mg^{+2}, O^{-2}

S. No.	*Oxidation*	*Reduction*
1.	Oxidation is a chemical process in which oxygen combines with other elements to produce oxide.	Removal of oxygen from a substance is called reduction.
2.	The removal of hydrogen from compound is oxidation.	Addition of hydrogen in a substance is reduction.
3.	The loss or removal of electrons from a substance is oxidation.	Addition or gain of electrons in a substance is reduction.
4.	Positive charges on a substance increases in oxidation.	Positive charge decreases in reduction.
5.	Generally oxidation takes place at electro-positive element.	Reduction takes place at electro-negative element.
6.	Example: $Na^0 \longrightarrow Na^+ + e^-$	Example: $Cl + e^- \longrightarrow Cl^-$

S. No.	*Oxidizing Agent*	*Reducing Agent*
1.	The donor of oxygen to a substance is called oxidizing agent.	The acceptor of oxygen form a substance is called reducing agent.

2.	The acceptor of hydrogen.	The donor of hydrogen.
3.	The acceptor of electrons from a substance.	The donor of electron to a substance.
4.	They are electropositive in nature.	They are electronegative in nature.
5.	Oxidizing agents are electrophiles.	Reducing agents are nucleophiles.

Solution of Textbook Progress Test - 7

Q.01 ***(a) "The ability of ion depends upon its charge density". Comment on the statement.***
(b) What is essential difference between hydration and hydrolysis ?

Ans. (a) See Q 9 on page 243.
(b) See differences 1 on page 270.

Q.02 ***What is ionization theory? How does it explain the conductance of electric current through solutions?***

Ans. See Q 11 and Q 15 on page 244 and 245.

Q.03 ***What is electrolysis? Explain by giving the example of $CuCl_2$. Give all necessary electrode reactions.***

Ans. See Q 12 and Q 15 on page 245.

Q.04 ***Write detailed note on electrode potential. What do you infer from the electrochemical series?***

Ans. See Q 16 & Q 22 on page 246 and 249.

Q.05 ***(a) Define Oxidation number, oxidation and reduction.***

Ans. See Q 23 & Q 24 on page 249 and 250.

(b) Give the oxidation number of :

(i) Cr in $K_2Cr_2O_7$ ***(ii) S in $Na_2S_2O_3$***
(iii) C in C_2H_6O ***(iv) Mn in MnO_4^-***
(v) N in NCl_3 ***(vi) O in OF_2***

Ans. See problems 17, 18 and 19 on page 265 and 266.

For (iii) **C in C_2H_6O**

Solution:

$$2C + 6(+1) - 2 = 0$$
$$2C + 6 - 2 = 0$$
$$2C = -6 + 2$$
$$C = \frac{-4}{2} = -2 \qquad C = -2 \quad \textbf{Ans.}$$

Q.06 ***Enumerate the rules for balancing the redox equations by ion electron method.***

Ans. See Q 27 on page 251.

Q.07 ***Balance the following equation by ion electron method.***

(i) $Cr_2O_7^{2-} + H^+ + I_2 \longrightarrow Cr^{3+} + IO_3^- + H_2O$

(ii) $MnO_4^- + SO_3^{2-} + H^+ \longrightarrow Mn^{2+} + SO_4^{2-}$

(iii) $Cr(OH)_3 + SO_4^{2-} \longrightarrow CrO_4^{2-} + SO_3^{2-}$ ***(Basic)***

(iv) ***Oxidation of Cl^- by MnO_4 in acid solution.***

$$KMnO_4 + KCl + H_2SO_4 \longrightarrow MnSO_4 + K_2SO_4 + H_2O + Cl_2$$

(v) $MnO_4^- + SO_3^{-2} + OH^- \longrightarrow Mn^{2+} + SO_4^{-2}$

Ans. *(i)* See problem 20 (b) on page 265. *(ii)* See problem 22 on page 267.
(iii) See problem 21 (a) on page 267. *(iv)* See problem 23 on page 268.
(v) $MnO_4^- + SO_3^{-2} + OH^- \longrightarrow Mn^{2+} + SO_4^{-2}$

Solution:

Break into two half reaction:

$SO_3^{-2} \longrightarrow SO_4^{-2}$ $\qquad$ $MnO_4^- \longrightarrow Mn^{2+}$

$SO_3^{-2} + 2(OH^-) \longrightarrow SO_4^{-2}$ $\qquad$ $4H_2O + MnO_4^- \longrightarrow Mn^{2+} + 8(OH^-)$

$2(OH^-) + SO_3^{-2} \longrightarrow SO_4^{-2} + H_2O$ $\qquad$ $5e^- + 4H_2O + MnO_4^- \longrightarrow Mn^{2+} + 8(OH^-)$ ___ *(b)*

$2(OH^-) + SO_3^{-2} \longrightarrow SO_4^{-2} + H_2O + 2e^-$ _____ *(a)*

Multiply eq. a by 5 and eq. b by 2:

$$10(OH^-) + 5SO_3^{-2} \longrightarrow 5SO_4^{-2} + 5H_2O + 10e^-$$
$$10e^- + 8H_2O + 2MnO_4^- \longrightarrow 2Mn^{2+} + 16(OH^-)$$
$$5SO_3^{-2} - 3H_2O + 2MnO_4^- \longrightarrow 5SO_4^{-2} + 2Mn^{2+} + 6(OH^-) \quad \textbf{Ans.}$$

Q.08 ***What are indicators? How can you explain their behavior?***

Ans. See Q 28 on page 252.

Q.09 ***Write notes on:***
(i) pH (ii) neutralization (iii) Buffers

Ans. See Q 32, 35 and 38 on page 253, 255 and 256.

Q.10 ***Define pH. What is pH of 0.1M HCl at 25°C ?***

Ans. See Q 32 on page 253.

HCl is strong acid. It ionizes completely into H^+ and Cl^-.

$[H^+] = 0.1M = 1 \times 10^{-1}$ mol/l

$pH = -\log[H^+]$

$pH = -\log[1 \times 10^{-1}]$

$pH = -[\log 1 \times \log 10^{-1}]$ (as log 1 = 0)

$pH = -[0 + (-1)]$

$pH = 1$ **Ans.**

Q.11 ***What are strong and weak acids and bases? Give appropriate examples.***

Ans. See Q 31 on page 253.